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CONTENTS

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The Coordinator
Malawi Journal of Aquaculture and Fisheries
Bunda College of Agriculture
P.O. Box 219
Lilongwe
Malawi
E-mail: dadeka@yahoo.com
dkassam@bunda.unima.mw

YIELD AND SPAWNER BIOMASS-PER-RECRUIT ANALYSIS OF *LETHRINOPS GOSSEI* (MORECHAL 1991) *(*CHISAWASASAWA) IN THE SOUTH EAST ARM OF LAKE MALAWI

‡**Gideon, B.W., Kaunda, E.K., Kassam, D., Msukwa, A.V. and Valeta, J.S.**

Bunda College of Agriculture (University of Malawi), P.O. Box 219, Lilongwe, Malawi
‡The author to whom correspondence should be addressed: bgideone@gmail.com

Abstract

A study to assess the yield and spawner biomass-per-recruit of *Lethrinops gossei* (Morechal 1991) (locally known as Chisawa-sawa) in the southeast arm of Lake Malawi was conducted using length data collected from December, 2006 to January, 2007 by Malawi Fisheries Research Institute, Mangochi, Malawi. Length and age-based growth, mortality and sexual maturity parameters for *L. gossei* were estimated and used in per-recruit models. The yield-per-recruit and spawner biomass-per-recruit models were run using per-recruit Tony Excel work sheet. Results suggest that *L. gossei* species is over-exploited with spawner biomass-per-recruit at 49 % of pristine levels. It is recommended that the current fishing level (0.48 year^{-1}) be reduced by 6 % to attain $F_{0.1}$ target reference point level which should subsequently reduce the exploitation rate by 18 % to attain the recommended optimum exploitation rate of any fishery of 0.5. This will lead to sustainable exploitation of *L. gossei* in the southeast arm of Lake Malawi.

Keywords: Yield-per-recruit; Spawner biomass-per-recruit; Target reference point; *Lethrinops gossei;* Exploitation.

Introduction

Current status of the fishery in Malawi

Following the decline of the inshore stocks found in water depths of less than 30 m, fishing pressure is now directed towards the relatively less exploited offshore stocks found in water depths of greater than 30 m that comprises about 80 % of the lake's area (Menz, 1995). Among the stocks is *Lethrinops gossei* whose population dynamics like yield per-recruit (YPR) and spawner biomass per-recruit (SBR) is fully not known. Moreover recruitment, (how much fish of this stock enter the fishery) is not known. This is against the fact that recent assessment indicates that additional fish will have to be drawn from the deep water community (Duponchelle *etal.,* 2000) where *Lethrinops gossei* locally known as Chisawasawa is one of the most principal targets because of its economic importance. The species is, commercial and can be used for aquarium hence needs to be sustainably exploited and managed basing on scientific advice.

Lethrinops gosseii as a potential indicator species for over exploitation

The Genus *Lethrinops* contains more than 38 species and belongs to a family of Cichlidae, sub family Pseudocrenilabrinae, order Perciforms and class Actinopterygii (ray finned fishes). *L. gossei* (Figure 1) is one of the haplochromine cichlids, endemic to the Lake Malawi basin and is characterized mainly by the shape of the lower jaw and by the dentition. *L. gossei* is a benthivore and feeds through picking up substrate and sorting prey (Wootton, 1998).

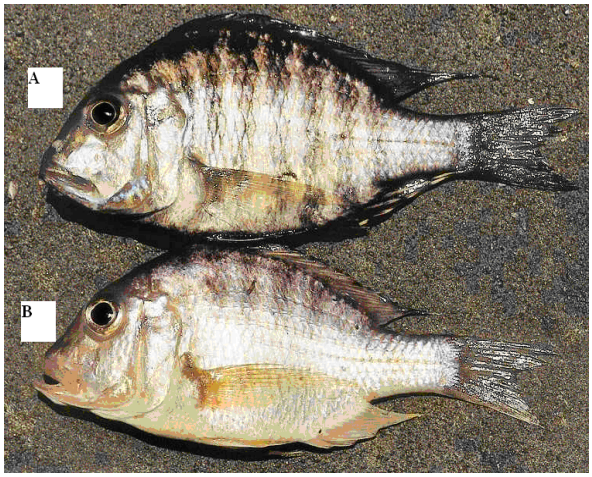


Figure 1: Photograph of male (A) and female (B) *Lethrinops gossei* caught using demersal trawl gear at a depth of >75 m from the South East arm of Lake Malawi (photo by Singini, 2006).

The species is demersal fresh water species occurring at a depth of 46-128m at muddy bottoms and forms one of the major species of commercial importance in the deep water zone (Ribbink, 1994; Wootton, 1998) *L. gossei* is said to be precocial (k-selected) fish producing very few young ones at a time and consequently unlikely to recover quickly from heavy fishing pressure (Ribbink, 1994) hence the species could be used as an indicator of over exploitation for the deep-water species in the Southern East Arm (SEA) of L. Malawi.

Yield and Spawner Biomass-per-Recruit (YPR) for *Lethrinops gossei*

Yield-per-recruit is a model for estimating the expected lifetime yield and biomass from a cohort subjected to

varying levels of fishing mortality (Gabriel *et al*., 1989). The overall objective of *YPR* analyses is to maximize yield from a fishery (Haddon, 2001). Yield- per-recruit analysis gives a target fishing mortality (the mortality rate to aim for) and a target age at first capture. The age at first capture can be used to set regulations regarding gear type (e.g., mesh sizes, hook sizes, escapement levels, minimum sizes) while the target fishing mortality can be used to set a constant fishing rate harvesting strategy- which is one of the possible options when managing a fish stock. being constant. The *YPR* analyses assumes that the fishery concerned has reached equilibrium with the given fishing mortality and natural mortality and the growth characteristics of the population being constant. Estimates of optimum age/ size at first capture and optimum fishing mortality: It assumes that the fishery concerned has reached equilibrium with the given fishing mortality, and natural mortality and the growth characteristics of the population are constant with stock size. In order to alleviate these uncertainties, $F_{0.1}$ (fishing mortality at 10% of maximum yield-per-recruit) is generally used instead of F_{MAX} (maximum fishing mortality) (Haddon, 2001).

Spawner biomass- per- recruit (SBR) is one of the tools used in fisheries management. It involves estimating fishing mortality to a level at which the spawner biomass-per-recruit is reduced to a target reference point (TRP) (Clark, 1991). Reference point is the state or value of some indicator (e.g. spawning stock) which corresponds to a desirable or undesirable position that requires urgent action (King, 1995). SBR is highly dependent on the density of adult fish. This provides a good basis of management by focusing on maintenance of good level of SBR. Pitcher and Hart, (1982) reported that fish enter the fishery (recruitment) through reproduction hence spawner biomass needs proper management.

King (1995) showed that yield-per-recruit models examine the trade off between capturing a large number of smaller fish in their life span and capturing a smaller number of larger fish later in their life span. It was also reported that yield per recruit model considers the dependence of yield upon growth, age at first capture, and fishing mortality Beverton and Holt, 1957). Growth, mortality and stock size are the main determinants of yield and aspects such as the timing of spawning and recruitment are important when considering management strategies (King, 1995). Recruitment is defined as the process in which young fish enter the exploited area and become liable to contact with the fishing gear (Beverton and Holt, 1957; Gulland, 1969). Knowledge of recruitment patterns is a requisite for modern fisheries management.

As the fishing pressure in Lake Malawi is now directed towards the offshore stocks found in water depths of greater than 30 m, *L. gossei* becomes one of the principal targets of multispecies fishery in the SEA of L. Malawi. Unfortunately no management guidelines for sustainable exploitation of offshore species exists due to limited scientific information required for formulation of such management guidelines. This study used per-recruit models to assess the yield and spawner biomass-per-recruit of *Lethrinops gossei* in the SEA of Lake Malawi to provide information that can be used to formulate guidelines to sustainable exploitation of *L. gossei* in the SEA of Lake Malawi.

Materials and methods

The study area

The study was conducted in areas B and C of SEA of L. Malawi shown in Figure 2.

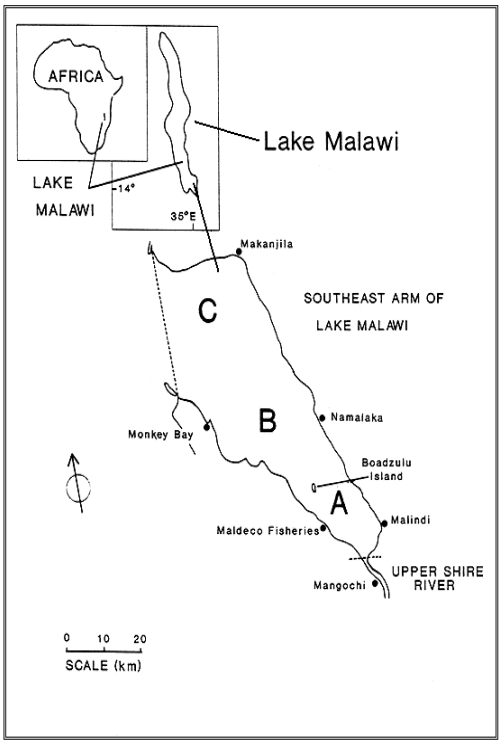


Figure 2: Map showing the study area. Source: GOM/FAO/ UNDP

Estimation of Growth Parameters

Growth parameters were estimated by using length-at-age which was modeled using the three-parameter von Bertalanffy growth model (VGBF), which is described as:

$$L_t = L_\infty\left(1-e^{-K(t-to)}\right)$$

where *Lt* is length at time *t*, L_∞ is the theoretical asymptotic length, *K* is the body growth coefficient that determines the rate at which L_∞ is attained, and t_0 the age of zero length fish. The Von Bertalanffy growth model

was fitted to the observed length-at-age data for *L. gossei* using an iterative least squares procedure (Microsoft EXCEL) SOLVER routine with Newton algorithm option. Recommendations by Punt and Hughes (1992) for determining and fitting appropriate growth models were followed.

Ageing of *Lethrinops gossei*

The samples were aged by developing the length frequency key. Then this length frequency key was fitted in the length-at-age key.

Age-at-first Maturity

Length data measured using measuring board to the nearest 0.01mm of 175 fish samples of both sexes was used. Weight of individual fish to the nearest 0.01gram was obtained by converting observed total length (mm) into weight using $Wt = aL^b$ where *a* and *b* are the weight-length relationship parameters.

The age-at-sexual maturity in this study was determined by fitting a logistic ogive to the expected proportion of reproductively active fish. Since there were no observed proportions of reproductively active fish to be used for plotting the logistic ogive, expected proportions of reproductively active fish were used. These were obtained using maturity equation:

$$Mat_{50} = \frac{1}{(1+\exp(-Age-2.14/1.12)}$$

Where age ranged from 0, 1,2……..6. An age-length key was used to transform the length frequency distributions to age frequency distributions. The 2-parameter logistic ogive was fitted using a non-linear least squares procedure (Welcomme 2001) and is described by Booth and Buxton (1997) as:

$$P_a = \left(1+\exp^{-\left(a-a_{50}/\delta\right)}\right)^{-1}$$

where *Pa* is the percentage of mature fish at age *a*, a_{50} is the age at 50% sexual maturity and δ is the width of the ogive.

Age-Specific Selectivity

The age-specific selectivity of stern trawl fisheries was modeled in this study using the logistic model (Butterworth *et al..,* 1989) described as:

$$S_a = \left(\frac{1}{1+e^{-(a-a_{50})/\delta}}\right)$$

where S_a is the selectivity of the gear on a fish of age *a*, *a50* is the age-at-50%-selectivity, and δ is a parameter related to the age range over which the selectivity changes from values near 0 to values near 1. As δ tends to zero, this function approaches knife-edged selection (Butterworth *et al.,* 1989).Length-frequency data used for estimating the selectivity of the stern trawl fishery (demersal) was obtained from routine bi-annual demersal monitoring surveys of Lake Malawi which were undertaken from December, 2006-January, 2007 using the Department of Fisheries research vessel – the *R.V. Ndunduma* .

An age-length key was used to transform length frequency to age frequency. The inverse Von Bertalanffy Growth Equation was used to convert length data into age that was used in the per-recruit analysis when plotting the logistic selectivity ogive. The equation was expressed as follows:

$t_{(L)} = t_o - 1/K*Ln(1-L/L_\infty)$ (Sparre and Venema, 1992).

Estimation of Mortality Rates

A first approximation of the instantaneous rate of total mortality (*Z*) for *L. gossei* was estimated by catch-curve analysis (Ricker 1975). Catch curve analysis was applied to length frequency distributions, which were converted to age frequency distributions by means of a normalised age-length key (Butterworth *et* al., 1989). The length frequency distributions for *L. gossei* were obtained from the routine bi-annual demersal monitoring surveys of Lake Malawi which were undertaken in December, 2006-January, 2007 using the Department of Fisheries research vessel – the *R.V. Ndunduma*.

Natural mortality (*M*) was estimated using Pauly's empirical formula (Pauly 1980) of the form:

$Ln(M = 0.8 * \exp[-0.0152 - 0.279\times Ln(L_\infty) + 0.6543\times Ln(K) + 0.463\times Ln(T)]$

where L_∞ and *K* are the von Bertalanffy growth parameters, *T* is the mean lake temperature (^{0}C) and 0.8 is a constant. The mean annual water temperature on Lake Malawi is approximately 25 ^{o}C (Patterson and Kachinjika 1995). Fishing mortality *(F)* was obtained via subtraction as $F = Z-M$ (Gulland 1985) and finally the exploitation rate (*E*) was obtained by the ratio of *F* to *Z*.

Per-Recruit Analyses

Per-recruit analysis was conducted by constructing a model of the development of a cohort through time that takes into account the growth and mortality of individuals (Butterworth *et al*., 1989; King, 1995). This is based on the assumption that recruitment is constant and that the stock under consideration is at equilibrium (Butterworth *et al*., 1989; Sparre and Venema, 1998). In this study, F_{SB25} was assumed as a BRP where the stock is at a high risk of collapse, while $F_{0.1}$ and F_{SB40} were calculated as BRPs that would maximize long-term yield.

Yield- per recruit was calculated using the model that incorporates the catch equation and exponential survival function (Ricker, 1975).

$$\frac{Y}{R}=\sum_{t=t_R}^{t_\lambda}\left[W_t S_t F \frac{1-\exp^{-S_t F-M_t}}{S_t F+M_t} e^{-\sum_{k=t_R}^{t-1}(S_k F+M_k)}\right]$$

where S_t is the selectivity coefficient for fish of age *t*, F is the fishing mortality of completely recruited fish, M_t is the natural mortality at age *t*- assumed to be constant and M for all groups in *YPR* analysis, W_t is the average weight of fish for the t^{th} age class, t_R is the age of entry into the fishery, and t_λ is the maximum age of fish that still contributes to the fishery.

Similarly, spawner biomass-per-recruit as a function of F is described as:

$$\frac{S}{R}=\sum_{t=t_R}^{t_\lambda}\left[W_t \psi_t e^{-\sum_{k=t_R}^{t-1}(S_k F+M_k)}\right]$$

where Ψ_t is the proportion of fish at age *t* that are sexually mature, W_t is the begin-year mass of a fish of age *t* such that:

$$W_t = q(L_t)^b \text{ and } L_t = L_\infty (1-e^{-K(t-t0)})$$

where L_∞ ,K and t_0 are the von Bertalanffy growth parameters, q and b are the mass-length relationship parameters.

These models were run using Per-recruit Tony Excel Work sheet to get the output of *YPR* and *SBR* of *L. gossei* in the southeast arm of Lake Malawi. Yield and spawner biomass-per-recruit curves were produced using Microsoft excel.

Input parameters

All the input parameters for the per-recruit analyses were summarised in Table 1. Due to uncertainty associated with estimates of natural mortality (M), a range of M values (Table 1) were used in calculating the BRPs (Griffiths, 1997; Weyl, 1998; Malcolm, 2001)

Table 1: Summary of parameters used in per-recruit analyses for *Lethrinops gossei* in the southeast arm of Lake Malawi

Parameter	Value
L_∞ asymptotic length (mm, TL)	204.59 mm
K body growth coefficient	0.24 yr^{-1}
t_o age of zero length fish	0.00 yr
Z total mortality coefficient	0.79 yr^{-1}
M natural mortality coefficient	0.31yr^{-1} (range 0.21- 0.41)
F fishing mortality coefficient	0.48 yr^{-1}
A weight-length relationship	0.000009
B weight-length relationship	3.134
Age-at-maturity (M_{50}) logistic	2.14 yr
Age-at-maturity-Delta	1.12
Age-at-capture (t_c)-stern trawl logistic	2.60 yr
Age-at-capture-Delta	0.66
Maximum age (t_λ)	6 yrs
Proportion of stern trawl fishery	1

Estimation of $F_{0.n}$ and $F_{SB(x)}$

The value of $F_{0.n}$ was obtained numerically by solving the equation (Punt 1997):

$$\left.\frac{dYPR}{dF}\right|_{F=F_{0.n}} = 0.n \left.\frac{dYPR}{dF}\right|_{F=0}$$

where a slope of 10% and 0% corresponds to $F_{0.1}$ and F_{MAX} respectively. Fishing mortality corresponding to the quantity *FSB(x)* (fishing mortality that reduces spawner biomass-per-recruit to *x*% of the pristine (SBR)$F=0$) was obtained by solving the equation:

$$SBR_{CUR(x)} = (SBR_{F=0})\times(x)$$

Results

Ageing of *Lethrinops gossei*

Length-at-age key (Table 2) for *L. gossei* (n = 175) both male and female fish from the southeast arm of L. Malawi. The key shows that *L.gossei* can attain an age of 6 years with the length range of 170-174 mm TL.

Table 2: Length-at-age key for *Lethrinops gossei* from the southeast arm of Lake Malawi.

Length	Age (years)							
(mm TL)	0	1	2	3	4	5	6	**Total**
30-34								
35-39								
40-44								
45-49								
50-54	2							
55-59	1							
60-64								
65-69								
70-74								
75-79								
80-84	2							
85-89	4							
90-94	6							
95-99		3						
100-104		3						
105-109		6						
110-114			7					
115-119			10					
120-124			9					
125-129			12					
130-134			10					
135-139			15					
140-144				19				
145-149				18				
150-154					25			
155-159					8			
160-164						8		
165-169						5		
170-174							2	
N	15	12	63	37	33	13	2	**175**

Age-at-first Maturity

The logistic ogive illustrating the relationship between sexual maturity and age for *L. gossei* fish (both male and female fish) is shown in Figure 3. The age-at-50% sexual maturity was estimated at 2.14 years and corresponded to a total length of 134 mm.

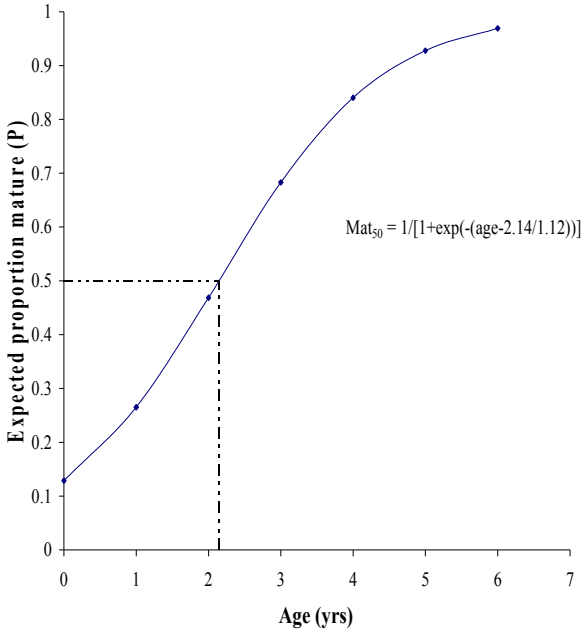


Figure 3: Proportion of sexually mature *Lethrinops gossei* fish -at -age sampled from the southeast arm of Lake Malawi (n = 175).

Age-specific selectivity

Selectivity of stern (dermesal) trawl fishery for L. gossei in the southeast arm of Lake Malawi is illustrated in Figure 4. The age-at-(50%)-selectivity was estimated at 2.6 for the stern trawl (dermesal) fisheries. This age corresponded to total length of 141 mm.

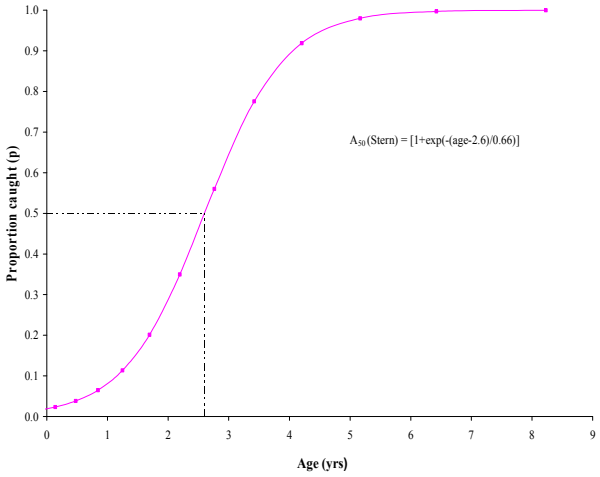


Figure 4: Selectivity gives for *Lethrinops gossei* in the Stern trawl (n = 175) fishery of the southeast arm of Lake Malawi.

Mortality

Natural mortality (M) was estimated at 0.31 year^{-1}. Total annual mortality was estimated at 0.79 year^{-1} using catch-curve analysis method (Figure 5). Fishing mortality was obtained by subtraction (i.e. $F = Z - M$) at 0.48 year^{-1}.

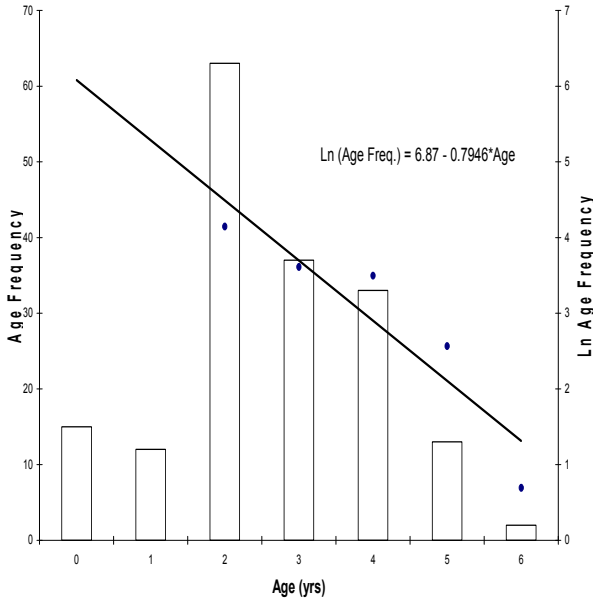
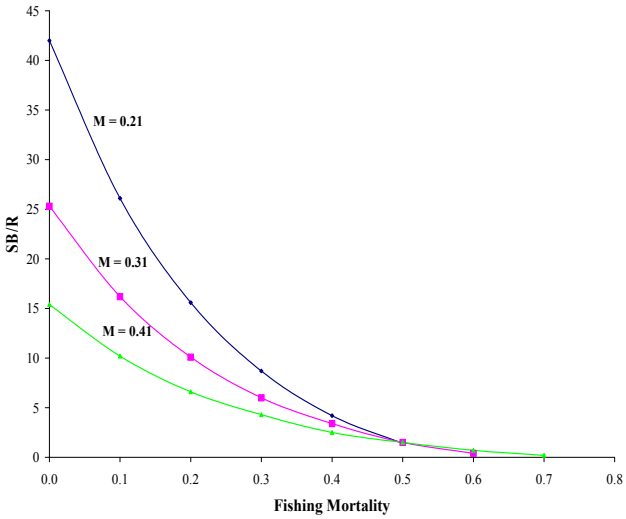


Figure 5: Age frequency distribution (bars) and catch curve (solid dots) for Lethrinops gossei caught in the southeast arm of Lake Malawi. The slope of the descending limb of the catch curve provides an estimate of total mortality (Z).

Per-Recruit Analysis

Yield-per-recruit and spawner biomass-per-recruit curves for *L. gossei* from the southeast arm of Lake Malawi at the current age-at-capture (t_c = 2.6 years) and at three levels of natural mortality (0.21, 0.31 and 0.41) are presented in (Figure 6) and (Table 2).



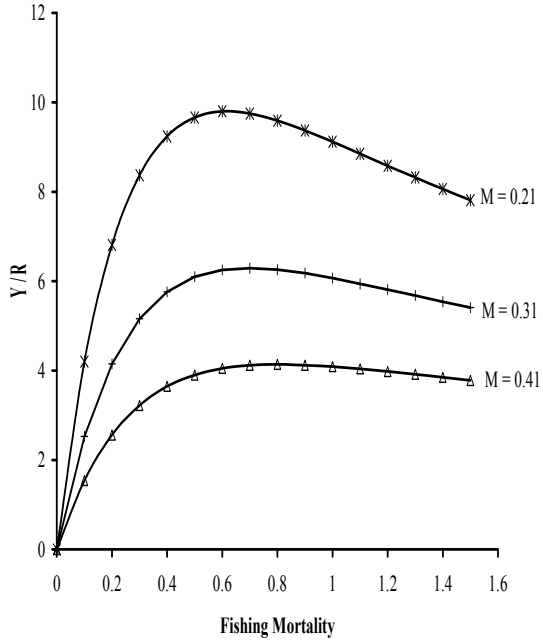


Figure 6: Spawner biomass-per-recruit (SBR) and Yield-per-recruit (YPR) as functions of fishing mortality for *Lethrinops gossei* in the southeast arm of Lake Malawi at different levels of natural mortality (M), t_c = 2.6 years.

Currently, the level of natural mortality (M) which is the base case scenario is 0.31 yr^{-1}. Maximum yield-per-recruit fluctuated widely with changes in natural mortality (Figure 6; Table 2) with highest levels attained at the lowest natural mortality (0.21 yr^{-1}). Exploitation levels corresponding to $F_{0.1}$ and F_{MAX} are observed to increase with increasing natural mortality. F_{MAX} and $F_{0.1}$ ranged from 0.60 to 0.80 yr^{-1} and from 0.40 to 0.50 yr^{-1}, respectively (Figure 6; Table 2), suggesting that productivity decreases with increasing natural mortality. Fishing mortality was highest (0.58 yr^{-1}) at the lowest level of natural mortality (M = 0.21 yr^{-1}) and ranged between 0.38 - 0.58 yr^{-1}. At the current level of natural mortality (i.e. base case scenario M = 0.31 yr^{-1}) fishing mortality (F) exceeded $F_{0.1}$.

SBR also declined rapidly with increased fishing mortality (Figure 6) for all levels of natural mortality (0.21 – 0.41 yr^{-1}). F_{SB50}, F_{SB40} and F_{SB25} ranged between 0.45 - 0.55 yr^{-1}, 0.60 – 0.75 yr^{-1} and 1.05 – 1.35 yr^{-1} respectively (Figure 6; Table 2). The spawner biomass-per-recruit as a percentage of the pristine unfished condition ranged from 41% to 52% for natural mortality between 0.21 and to 0.41 yr^{-1}, while spawner biomass-per-recruit at the current (SBR_{cur}) level of natural mortality (M = 0.31 yr^{-1}) was estimated at 49% $(SB/R)_{F=0}$.

Discussion

Length-at-age key (Table 2) indicated that *L. gossei* can attain an age of 6 years. This implies that the species is relatively a long-lived species. The finding concurs with what was reported by Singini, (2006 unpublished thesis) that the species is relatively long-lived, with a

maximum recorded age of 6+ years. The study showed that *L. gossei* matures in its second year of life (Figure 3) and this implies that it is a relatively slow-growing species. This statement was supported by the von Berlanffy growth parameter which was small $9*10^{-6}$ (Sparre et *al.,* 1989).

The age-at-50% selectivity of *L. gossei* for this study was estimated at 2.60 years. This is similar with what (Singini, 2006 unpublished thesis) found and this was attributed to the same gear cod-end mesh size (38 mm), vessel, species and site of sampling (Sparre and Venema, 1992). The determination of growth, maturity and selectivity parameters in freshwater fishes are locality specific and the determination of these parameters forms the basis for management in each particular water body. Since the harvesting of a fishstock after the attainment of 50%-maturity reduces the risk of spawning failure (Weyl, 1998), the determination of the size-at-50% maturity should be the first priority. By comparing the size-at-selectivity of each species harvested in each fishery to the age-at-maturity, the sustainability of each gear can be assessed.

Natural mortality was estimated at 0.31 $year^{-1}$ using Pauly's empirical model which was multiplied by 0.8 to account for mouth brooding behaviours, reproduction physiology and other behaviours of dermesal cichlids (Pauly, 1983). This estimate was accepted as being within the expected range for *L. gossei* as cichlids are expected to have a low natural mortality due to the high degree of parental care and relatively long life span (Wootton,1998). Total mortality (*Z*) was estimated at 0.79 $year^{-1}$ using catch curve analysis

Current exploitation rate for *L. gossei* in areas B and C lies between the $F_{0.1}$ and F_{MAX} TRP levels and corresponds to an SBR reduction to 49% of pristene levels (Figure 6; Table 3).

Table 3: Summary of yield-per-recruit and spawner biomass-per-recruit as functions of fishing mortality (with biological reference points) for *Lethrinops gossei* in the southeast arm of Lake Malawi at different levels of natural mortality (*M*), t_c = 2.6 years.

M	$F_{0.1}$	F_{MAX}	F_{SB50}	F_{SB40}	F_{SB25}	F_{CUR}	*SBR cur %*
0.21	0.40	0.60	0.45	0.60	1.05	0.58	0.41
0.31	0.45	0.70	0.50	0.65	1.15	0.48	0.49
0.41	0.50	0.80	0.55	0.75	1.35	0.38	0.52

The declining *L. gossei* catch in the SEA of Lake Malawi over the past years (FRU unpublished catch statistics; Weyl, 1998; Bulirani *et al*., 1999) implies that this level of SBR is low to sustain the *L. gossei* stock. This may in part, be a consequence of the reproductive behaviour of *L. gossei*. *Lethrinops* spp. are mouth brooders which brood their eggs and young for extended periods (Trewawas, 1983). For this reason the recruitment of *L. gossei* is likely to be highly dependent on the density of adult fish and *L. gossei* directed management should focuss on the maintenance of the SBR at $F_{0.1}$ or even F_{SB50} levels. Management at these TRPs would require a decrease of 6% in *F* to attain the $F_{0.1}$ and a 4 % increament in *F* to attain the $F_{SB50.}$ The F_{MAX} approach has not been considered because has received some criticism in the past (Punt 1993), and the $F_{0.1}$ TRP is considered to be more robust management strategy (King, 1995). However, it should be recognized that the F_{MAX} and $F_{0.1}$ strategies do not take into account whether sufficient spawner biomass is conserved to ensure sufficient recruitment in the future (Deriso, 1987; Punt, 1993). It is also recognised that the per-recruit approach has limitations, such as its assumption of constant recruitment (Perreiro, 1992), and therefore, its use as a predictive tool is limited to short term predictions. It is crucial that relevant long-term directed catch-at-age or –length data are collected in all fisheries, to allow for the combination of the per-recruit data with other age-structured models in order to provide more accurate, comprehensive and sustainable strategies for long-term management.

The three-dimensional modeling approach indicates that current exploitation levels are relatively above F_{SB40} suggesting that these levels are detrimental to recruitment. Therefore, the population is expected not to grow and become unstable. The approach also showed that $F_{0.1}$ harvesting strategy is more sensitive than F_{SB40}. This means that currently the fishery is being overfished as current fishing mortality (0.48) is greater than $F_{0.1}$ (0.45) at current natural mortality of 0.31 $year^{-1}$.

The three-dimensional modeling approach has proved to be a very useful tool for describing the response of yield and spawner biomass-per-recruit to different combinations of age-at-capture, fishing and natural mortalities.

Information obtained from such analyses includes the age-at-capture that optimizes yield and the highest exploitation level that a fishery can sustain based on the *F0.1* harvesting strategy. The results of these analyses indicate that yield in the *L. gossei* fishery in the southeast arm is optimised at an age-at-capture of 5 years and above. The current age-at capture (2.6 years) is, therefore, lower than the age at which yield is optimised (i.e. 5 years). This suggests that the fishery is over exploited. These analyses have also revealed that the *L. gossei* fishery in the southeast arm of Lake Malawi can probably withstand exploitation levels of close to 0.63 $year^{-1}$ based on the $F_{0.1}$ harvesting strategy at *M* = 0.41 which is slightly above the current exploitation level (i.e. 0.61 $year^{-1}$). However, F_{SB40} is the recommended harvesting strategy as the $F_{0.1}$ strategy does not take into account the effects of fishing on the spawning stock and subsequent recruitment (Clarke, 1993; Punt, 1993). Thus the exploitation level corresponding to F_{SB40} (i.e. 0.49 yr^{-1}) is instead recommended as the highest exploitation level that the fishery can withstand.

Thompson *et al*. (1995) also reported similar findings. In his analyses using the Beverton and Holt dynamic pool model, he observed that for *D. limnothrissa*, fishing levels in excess of 0.5 year^{-1} would result in recruitment over-fishing and stock collapse. Basing on these recommendations, these analyses revealed that *L. gossei* fishery in the southeast arm of Lake Malawi was over fished as the current F_{SB40} exploitation level is 0.82 year^{-1} which is very high.

Conclusion

The results suggest that *L. gossei* from the southeast arm of Lake Malawi is over exploited as the current fishing mortality (0.48) is above $F_{0.1}$ (0.45) TRP level which is regarded as a more robust management strategy for a fishery. Being a k-selected species, this fishing mortality (0.48 yr^{-1}) may not allow the species to easly recover from this fishing pressure.

The current exploitation rate for *L. gossei* in areas B and C in the southeast arm of Lake Malawi lies between the $F_{0.1}$ and F_{MAX} TRP levels and corresponds to an SBR reduction to 49% of pristine levels. Management of this fishery at $F_{0.1}$ TRP would require a reduction of 6% in F to attain the $F_{0.1}$ TRP level.

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References

Beverton, R.J.H and Holt, S.J. 1957. On the dynamics of exploited fish populations, Chapman and Hall, New York, USA.

Booth, A.J. and Buxton, C.D. 1997. The biology of the panga, *Pterogymnus laniarius* (Teleostei: Sparidae), on the Agulhas Bank, South Africa. *Environ. Biol.Fish.* 49: 207-226.

Bulirani, A.E., Banda, M.C., Palsson, K.P., Weyl, O.L.F. Kanyerere, G.Z., Manase, M..M and Sipawe, R.D. 1999. Fish Stocks and Fisheries of Malawian Waters. Resource Report 1999. Government of Malawi, Fisheries Department, Lilongwe, 54 pp.

Butterworth, D.S., Punt, A.E., Borchers, D.L., Pugh, J.G., and Hughes, G.S. 1989. A manual of Mathematical techniques for linefish assessment. *S.Afr. Natl. Sci. Pro. Rep.,* 160: 89 pp.

Clark, W.G. 1991. Ground fish exploitation rates based on life history parameters. *Can. J. Fish. Aquat. Sci.,* 48: 734-750.

Clarke, W.G.1993. The effect of recruitment variability on the choice of a target level of spawning biomass -per-recruit. In *Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations.* Kruse, G., Eggers, D.M., Marasco, R.J., Pautzke, C. and T.J. Quinn II (Eds). Alaska Sea Grant Rep., 93-02: 233-246.

Deriso, R.B. 1987. Optimal *F0.1* criteria and their relationship to maximum sustainable yield. *Can. J. Fish. Aquat.Sci*. 44 (Suppl. 2): 339-348.

Duponchelle, F., Ribbink, A.J., Msukwa, A., Mafuka, J. and Mandere, D. 2000. Growth Patterns of some of the most important fish species caught by demersal trawling In the South West Arm of Lake Malawi. In: Duponchelle, F. and Ribbink,A. J. (eds). Fish Ecology Report. Senga Bay, Lake Malawi/ Nyasa/ Niassa Biodiversity Conservation Project, pp.169- 188.

Gabriel, W.L., Sissenwine M.P. and Overholtz W.J. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank Haddock. N. Amer. J. Fish. Manage. 9: 383-391.

GoM/FAO/UNDP, 1993. Chambo Fisheries Research Project. *FAO, Fisheries management in the southeast arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (Oreochromis spp.).*CIFA Technical Paper. No. 21. Rome,113 pp.

Griffiths, M.H. 1997. The application of per-recruit models to *Argyrosomus inodorus,* an important South African sciaenid fish. *Fish. Res.,* 30: 103-115.

Gulland, J. A. 1969. Manual of methods for fish stock assessment, Fish Stock Evaluation Branch, Fishery Resources and Exploitation Division, Fao, Rome. pp. 99-101.

Haddon, M. 2001. Modeling and Quantitative Methods in Fisheries. Chapman & Hall/ CRC, Florida.

King, M. 1995. Fisheries biology, assessment and management. Fishing News Books, Oxford, UK.

Malcolm, H. 2001. Modeling and Quantitative Methods in Fisheries. Chapman and Hall, Boca Raton, 406pp.

Marechal, C. 1991. *Lethrinops*. PP 233-240. In J. Daget, J.P. gosse, G.G. Tengels and D.F.E Thys van den Audenaerde (eds). Checklist of the fresh water fishes of Africa (CLOFFA). ISNB, Brussels; MRAC Tervuren; and ORSTOM, Paris. Vol.4.

Menz, A. (ed.) 1995. The fishery potential and productivity of the pelagic zone of Lake Malawi/ Niassa. Chatham, UK: Natural Resources Institute. 386pp.

Patterson, G. and Kachinjika, O. 1995. Limnology and Phytoplankton Ecology. In The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa. Menz, A. (Ed). Chatham; Natural Resources Institute: 1-67.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks . FAO Fish. Tech. Paper, (234): 52 p.

Pereiro, J.A. 1992. Some conceptual remarks on yield

per recruit. Fish. Res. 13: 423-428.

Pitcher, T. J. and Hart, P.J.B. 1982. Fisheries Ecology. AVI publishing West port, CT, 77-108 pp.

Punt, A.E. & Hughes, G.S. 1992. PC-YIELD II User's Guide. Benguela Ecology Programme R e p o r t No. 26, Foundation for Research and Development, South Africa. Quick, A.J.R. and Bruton, M.N. 1984. Age and growth of Clarias gariepinus in the P.K. le Roux Dam, South Africa. S. Afr. J. 2001. 19: 37-45.

Punt, A.E. 1993. The use of spawner-biomass-per-recruit in the management of linefisheries. In *Fish, Fishes and Fisheries.* Beckley, L.E. and R.P. van der Elst (Eds) Proceedings of the second South African Marine Linefish Symposium, Oceanographic Research Institute, Special publication (2): 80-89. Priestley, M.B. 1981 Spectral analysis and time

Punt, A.E. 1997. The Performance of VPA-based management. *Fish. Res.* 29:217-243.

Ribbink, A.J. 1994. Lake Malawi. pp. 27 – 33 in Martens, K., B. Goddeeris, and G. Coulter (eds.),

Speciation in ancient lakes. Archiv für Hydrobiologie Advances in Limnology, Volume 44: X + 508 pages, ISBN 3-510-47045-1.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can., 191: 1-382.

Sparre, P. and Venema, S. C., 1992. Introduction to tropical fish stock assessment. Part-1 Manual, *Fao Paper.* 66pp.

Sparre, P. and Venema, S.C. 1998. Introduction to Tropical Fish Stock Assessment, Part 1 Manual. *F.A.O Fish Tech. Pap*. 306/1, Rev. 2.

Sparre, P., Ursin, E. and Vene ma, S.C. 1989. Introduction to Tropical Fish Stock Assessment. Part 1 Manual. *FAO Fish Tech. Pap.* 306/1, 337 pp.

Thompson, A.B., Allison, E.H., Ngatunga, B.P. and Bulirani, A. 1995. Fish Growth and Breeding Biology. In *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa.* Menz, A. (Ed) Chatham; Natural Resources Institute: 279-306.

Trewawas, E. 1983. Tilapiine Fishes of the genera *Sarotherodon, Oreochromis* and *Danakila*. British Museum (Natural History) Publication No. 878. 583 pp.

Welcomme, R.L. 2001. Inland Fisheries: Ecology and management. Oxford, Blackwell Science, 358 pp.

Weyl, O. L. F. 1998. The dynamics of a subtropical lake fishery in central Mozambique, Rhodes University, South Africa.

Weyl, O.L.F. 2001. Hard choices for chambo management in Area A of the southeast arm of Lake Malawi. Pages 146-155 in: Weyl, O.L.F., and M.V. Weyl (eds.). Proceedings of the Lake Malawi Fisheries Management Symposium, 4th- 9th June 2001. Government of Malawi.

Wootton, R.J. 1998. Ecology of Teleost Fishes. Kluwer Academic Publishers, Dordrecht, 386 pp.

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REMOVAL OF AMMONIA FROM AQUACULTURE WATER USING MAIZE COB ACTIVATED CARBON

Sichula J. [1], Makasa M. L. [2], Nkonde G. K. [2], Kefi A. S.[3], and ‡Katongo C.[2, 4]

[1]Environmental Council of Zambia, P. O. Box 71302, Ndola, Zambia
[2]Copperbelt University, School of Technology, Chemical Engineering Department, P. O. Box 21692, Kitwe, Zambia
[3]National Aquaculture Research and Development Centre, Department of Fisheries, P. O. Box 22797, Kitwe, Zambia.
[4]The University of Zambia, School of Natural Sciences, Department of Biological Sciences, P.O. Box 32379, Lusaka, Zambia
‡The author to whom correspondence should be addressed: katongo1960@yahoo.co.uk

Abstract
Experiments to investigate the use of activated carbon to remove ammonia in aquaculture were conducted at the National Aquaculture Research and Development Centre (NARDC), Kitwe, Zambia. The activated carbon was produced from the maize cob residue. The raw material was carbonized by partial combustion with limited amount of air. The carbonized material was then activated using steam at a pressure of 1.8×10^5KPa and was later processed into powder and granular activated carbon. Each of the four 100 litre experimental water tanks were stocked with 10 fingerlings of an average weight of about 12g and fed with a 40% crude protein feed at 10% of body weight per day. Three (3) hours after stocking, water samples were taken and tested for ammonia. All the four tanks indicated positive results for the presence of ammonia with an average amount of 0.05mg/l. Twenty (20) grams of granular activated carbon was applied to the three treatment tanks after the first three hours, the fourth tank being a control with no activated carbon. Water samples were then taken every three hours to determine the amount of ammonia. The concentration of ammonia showed a sharp decline in the first five hours after application of activated carbon, indicating that ammonia was being adsorbed to carbon. The results from this study indicate that ammonia can be removed from the aquaculture water using activated maize cob carbon.

Key words: Granular activated carbon, carbonization, aquaculture, ammonia, adsorption

Introduction

Ammonia is the major waste product in the elimination of excess amino acids from the breakdown of proteins in fish (Durborow *et al.,* 1997). When fish is fed with high protein diet, they utilise the amino acids from protein digestion and excess amino acids are converted to ammonia which is excreted through the gills and in the faeces. The amount of ammonia excreted by fish varies with the amount of feed that is put into the pond or the species of fish being cultured and it increases with feeding rates (Durborow *et al*., 1997). The primary site for ammonia production is the liver while excretion is through the kidneys. In terrestrial animals, ammonia is converted to urea, a less toxic substance, by the enzyme carbamoyl phosphate synthase and is released through urine. However, fish lack this mechanism and can only eliminate ammonia from their bodies by direct excretion. In water, ammonia occurs in two forms represented as ammonium ions (NH_4^+) and unionised ammonia (NH_3). Between the two forms, the unionized form (NH_3) is more poisonous to fish (Pillay, 1991; Durborow *et al*., 1997).

Ammonia is acutely toxic to fish and can cause loss of equilibrium; increased breathing, cardiac output, and oxygen uptake, and in extreme cases; convulsions, coma and death. Fish exposed to low levels of ammonia, overtime, are more susceptible to bacterial infections and will not tolerate routine handling (Svobodova *et al*., 1993). The first signs of ammonia toxicity include slight restlessness, increased respiration and the fish congregating close to the water surface. Affected fish lie on their side and spasmodically open their mouths and gill opercula wide, followed by a short period of apparent recovery. The fish return to normal swimming and appear slightly restless. The skin of ammonia poisoned fish is light in colour, and covered with a thick or excessive layer of mucus.

Even at very low concentrations, ammonia still produces many effects in fish including; bacterial infections, reduction in egg hatching success, reduction in growth rate and morphological development, and pathological changes in the tissue of the gills, liver and kidney (Svobodova *et al.,* 1993).

In a recent study (Kefi, 2008), *Oreochromis andersonii* was found to be susceptible to columnaris disease which is caused by the bacterium *Flexibacter columnaris* when ammonia exceeds 0.02mg/l. Several factors have been shown to modify acute ammonia toxicity in fresh water. Some factors alter the concentration of NH_3 in water by affecting the aqueous ammonia equilibrium, while other factors affect the toxicity of NH_3 itself, either by ameliorating or exacerbating its effects (Kefi, 2008).

Natural transformation of ammonia in fish pond water

In fish ponds, ammonia is transformed by bacterial species mainly *Nitrosomonas* and *Nitrobacter* from one form to another in the nitrogen cycle. The nitrification

is important in preventing the persistent accumulation of high ammonia levels in water. Nitrification is an oxygen – consuming process requiring two (2) moles of oxygen per mole of ammonium ions consumed and yielding hydrogen ions. Nitrification may lead to depletion of dissolved oxygen and acidification of the water medium. In the present study, the application of activated carbon is used to remove ammonia from aquaculture facilities by adsorption, in order to avoid oxygen depletion and toxicity and to make it possible to increase the stocking density of fish in the pond (Svobodova et al., 1993).

Activated carbon

Activated carbon is a form of carbon which has been treated in a special way that makes its surfaces highly adsorbent (Peterson and Lee, 1971). It differs from graphite by having a random imperfect structure which is highly porous over a broad range of pore sizes. Activated carbon has the strongest physical adsorption forces or the highest volume of adsorbing porosity. It is relatively inexpensive with an enormous specific surface area, typically about $1000m^2g^{-1}$ (Sincero and Sincero, 1996). In other words, a handful of activated carbon has a total area greater than that of a football field (Arcadio and Georgia, 1996). The enormous surface area of activated carbon means that only small amounts can be sufficient to capture significant quantities of pollutants by adsorption (Sincero and Sincero, 1996). Activated carbon can be processed in different forms such as; Powdered Activated Carbon (PAC) which is generally less than 0.75mm in size, Granular Activated Carbon (GAC) which has irregular shaped particles ranging from 0.2mm to 5mm in size and Extruded Activated Carbon (EAC) which is cylindrical in shape with diameter ranging from 0.8mm to 5mm (Sincero and Sincero, 1996).

Adsorption theory

Adsorption is a process by which ions or molecules present in one phase tend to condense and concentrate on the surface of another phase. Adsorption occurs when molecules in the fluid phase are held for a period of time by forces emanating from an adjacent surface. The surface represents a gross discontinuity in the structure of the solid, and atoms at the surface have a residue of molecular forces called the van Der Waals forces which are common to all surfaces. The only reason certain solids are designated "adsorbents" is that they can be manufactured in a highly porous form, giving rise to a large internal surface (Coulson and Richardson, 2002). In adsorption, molecules diffuse from the bulk of the fluid to the surface of the solid adsorbent forming a distinct adsorbed phase. Adsorption which can either be physical or chemical is therefore a surface phenomenon and the extent of adsorption depends on the surface area available (Coulson and Richardson, 2002).

Physical adsorption

Physical adsorption is due to gas molecules being held to the solid surface by van der waals forces and is sometimes referred to as van Der Waals adsorption. Physical adsorption occurs spontaneously and the adsorbate tends to occupy the entire adsorbent surface but this is hindered by desorption, a process that is the opposite of adsorption and is similar to diffusion. For every adsorptive concentration, there is a state of adsorption equilibrium, similar to the equilibrium between condensation and evaporation. The higher the adsorptive concentration the greater is the adsorption (Reynolds and Richards, 1996). However, physical adsorption occurs rapidly at low temperatures and decreases with increasing temperature, obeying Le Chateliers principle and requires heat uptake. Physical adsorption is a reversible process whereby the gas adsorbed into a solid can be removed under reverse conditions of temperature and pressure. The amount of adsorbed substance is often determined by the gain in weight of the adsorbent. Atoms or molecules of a solid surface behave like the surface molecules of a liquid. They are not surrounded by atoms or molecules of their kind. Therefore, they have unbalanced or residual attractive forces on the surface which can hold adsorbate particles. Activated carbon uses the physical adsorption process (Reynolds and Richards, 1996).

The amount of ammonia adsorbed by activated carbon can be estimated using the Freundlich isotherm equation (Reynolds and Richards, 1996):

$$Q_e = x/m = K[C]^{1/n}$$

where:

Q_e is the adsorption capacity of activated carbon, mg/l

x is mass of the adsorbate in mg adsorbed onto the mass of adsorbent m

K is the Freundlich adsorption coefficient, $(mg/g)(1/mg)^{1/n}$

[C] is the equilibrium concentration of adsorbate, mg/l

n is the empirical coefficient

Thus the adsorbed atoms or molecules can be held on the solid surface such as carbon by physical van Der Waal's forces or chemical forces due to residual valence bonds (Mattson and Harry, 1971; Sawyer and McCarty, 1978; Bahl *et al*., 2004). Hence the main objective of the study was to find out if activated carbon can significantly reduce ammonia concentration in aquaculture water. Hence, the main objective of the study was to find out if activated carbon made from maize cob residue can significantly reduce ammonia concentration in aquaculture water through adsorption.

Materials and Methods

Maize cob residue was the source of activated carbon (Figure 1). The maize cob residue was obtained from small scale farmers in Kamfinsa area of Kitwe on the Copperbelt Province of Zambia.

Figure 1: Maize cob residue used to prepare activated carbon.

Carbonization of the raw material

Maize cob residue was carbonized by burning the material partially with a very limited supply of air. This was achieved by using an empty five litre (5L) tin as a kiln. The tin was 0.225m high and had a diameter of 0.175m giving it the volume of 0.0054$m^{3.}$ Five holes each with a diameter of about 5.2mm were perforated on the lid of the tin as shown in Figure 2(a) to supply a limited amount of air during carbonization. The maize cob residue was tightly packed into the tin. The tin was able to hold about 3.3Kg of maize cob residue as shown in Figure 2(b).

(a) (b)

Figure 2. Perforated lid of an empty tin (a), raw maize cob residue packed for carbonization (b)

The lid of the tin was tightly closed and was then horizontally placed on fire as shown in Figure 3(a). The tin with the maize cob residue was rotated on the fire to ensure that the contents were uniformly burnt (Figure 3 (a)). The material was heated for about 30 minutes until smoke stopped coming out of the holes on the lid of the tin. The tin was then allowed to cool for 20 minutes before it was opened. After opening the lid, the material was removed. This process carbonized the material which turned black in colour but each individual cob residue still maintained its shape (Figure 3(b)).

(a) (b)

Figure 3: Maize cob residue being carbonized (a), carbonized maize cob residue (b)

Activation of carbonized material

The carbonized material was sliced using a sharp blade. The slices were about 5– 6mm thick (Figure 4 (a)). The surface of the slices was observed under the Nikon NFX – 25 light microscope (Figure 4 (b)) at a magnification of 4.5 times before activation. The surface appeared rough with some isolated pores. The purpose of the observation was to see if pores were present on the slices before activation.

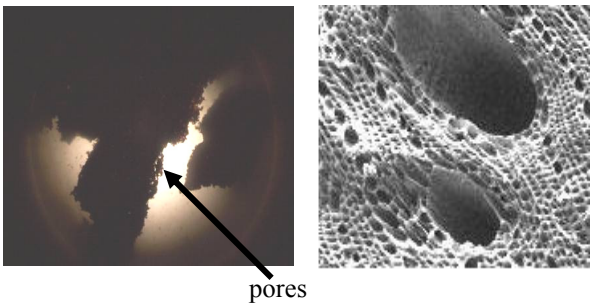
(a) (b)

Figure 4: Sliced carbonized material before activation (a), 'The Nikon NFX – 25' microscope (b) .

After observation, the slices were then put on a wire mesh and placed inside the autoclave. The temperature of the autoclave was set at 127˚C and the time was set at 30 minutes (Figure 5). The activation process started as the temperature started rising. When the temperature reading reached the set value (127˚C) the pressure had risen to 1.8g/cm² (1.77×10^8 Pascals). The temperature remained at 127˚C for 30 minutes and after that the pressure dropped to almost zero. The excess pressure was released using the pressure valve. The autoclave was allowed to cool for about 20 minutes before it was opened. The slices of carbon were taken out and observed under the microscope again. The number of pores on the surface of carbon increased which was an indication that steam activation had taken place.

Figure 5: The autoclave that was used to activate the carbonized material

The pores were not clearly captured in Figure 6(a) because the surface of the carbonized material was not flat enough to permit light to pass through and also because an ordinary camera was used to take pictures under a light microscope. Figure 6(b) shows the magnified pores on the surface of activated carbon as seen under the electron microscope.



(a) (b)

Figure 6: Microscopic view of activated carbon, under light microscope (a) and under electron microscope (b)

Processing of activated carbon

The activated carbon was crushed in a mortar and sieved through a 3mm sieve to obtain uniformly sized granular activated carbon (Figure 7). Each particle was about 3mm in size.

Figure 7: Processed activated carbon

Collection and conditioning of the fish used in the experiment

Ninety five (95) fingerlings of *Oreochromis andersonii* with average weight 3.235 ± 0.25g were caught from a concrete fish pond at the National Aquaculture Research and Development Centre (NARDC) at Mwekera in Kitwe, Zambia.

The fingerlings were put in a conditioning tank for two (2) days before the experiment was set up. During the conditioning period, the fingerlings were only supplied with air and no food was given to the fish. The aim of conditioning was to acclimatize the fish to tank conditions. Twenty-five (25) out of ninety five (95) fingerlings died (26% mortality) in the conditioning tank and after being conditioned for 2 days, the surviving fingerlings were transferred into experimental tanks.

Each experimental tank had a capacity of 100 litres ($0.1m^3$). A total of 4 experimental tanks were used comprising three treatments and one control. Sixty (60) litres of borehole water were put into each tank.

Application of activated carbon in experimental tanks

Ten fingerlings were stocked into each of the four tanks. Feed consisting of 40% crude protein was administered at 10% of the total body weight of the fingerlings in each tank. The four experimental tanks were setup in the morning at 10:00hrs and the fish were fed at the time of setup.

Twenty (20) grams of granular activated carbon were weighed and applied into tanks 1, 2 and 3 (treatment tanks). Tank 4 served as a control. Samples of water were collected from each of the four tanks every three (3) hours and tested for ammonia using the indophenol method (Svobodova *et al*., 1993). The four sets of water samples were collected and tested for ammonia; before application of activate carbon, and every three hours after application of activated carbon up to 18 hours. The mean concentration of ammonia was calculated for each of the three treatment tanks and the control. Correlation analysis was performed to describe the strength and direction of treatment and growth, nutritional and cost variables. If found strong ($r > 0.5$) regression analysis was performed too. All percentages and ratio data were transformed using arcsine values before analysis in an event of non – conformity. Statistical Package for Social Scientist (SPSS) 12.0 (SPSS Inc) software was used in analyzing the data.

Results

Table 1 shows that ammonia concentration in the treatment tanks reduced with increase in culture time and vice versa in the control tank.

Table 1: Ammonia accumulation in experimental tanks at different times of the experiment.

Tank #	Before application of activated carbon			3 hours after application of 20g carbon			6 hours after Application of 20g carbon			9 hours after Application of 20g carbon		
	NH_3 (mg/L)	pH	Temp (°C)	NH_3 (mg/L)	pH	Temp (°C)	NH_3 mg/L)	pH	Temp (°C)	NH_3 (mg/L)	pH	Temp (°C)
1(Treatment 1)	0.34	6.6	22	0.2	6.9	22	0.1	6.6	22	0.18	6.5	22
2 (Treatment 2)	0.62	6.9	22	0.42	6.9	22	0.41	6.5	22	0.22	6.7	22
3 (Treatment 3)	0.5	6.5	22	0.27	6.7	22	0.16	6.8	22	0.1	6.8	22
Treatment means	0.49	6.7	22	0.30	6.8	22	0.22	6.6	22	0.17	6.7	22
4 (Control)	0.43	6.5	22	0.49	6.5	22	0.53	6.5	22	0.65	6.5	22

A negative correlation between time and ammonia concentration was found to be significant ($r = -0.339$, $n = 20$, $P < 0.01$) As exposure time increased, the levels of total ammonia reduced until an equilibrium was achieved. The mean concentration of ammonia in each tank was then plotted against time to obtain the graphs in Figures 8, 9 and 10 below. When activated carbon (20g) was applied, there was a sharp decline in the first five hours thereafter the concentration of ammonia remained almost constant as shown in Figures 8 and 10.

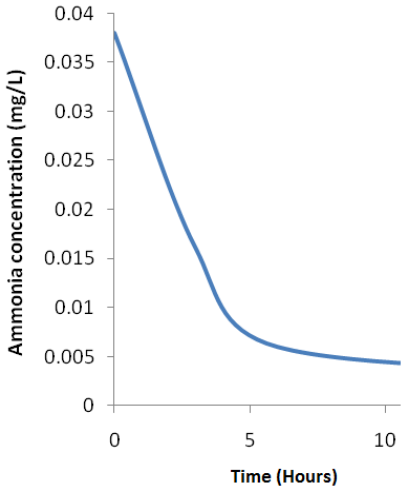


Figure 8. Ammonia concentration profile in a period of 9 hours following the application of 20g of activated carbon to the treatment tanks.

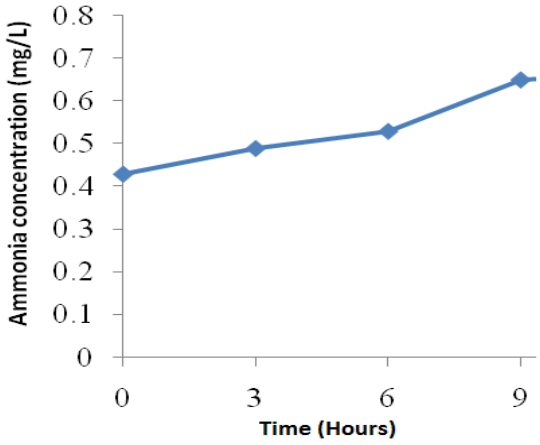


Figure 9: Amount of ammonia in the control tank during a period of 9 hours.

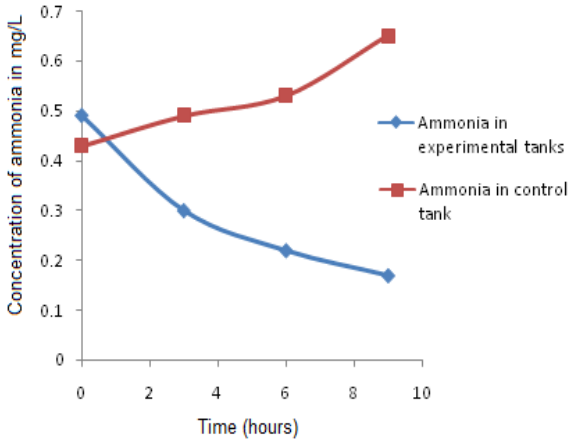


Figure 10. Ammonia concentration profile in the treatment and control during a period of 9 hours.

Discussion

The significant negative correlation between the concentration of ammonia in water and the time (hours) after the application of activated carbon this is an indication that ammonia was being removed from the water by adsorption. The fact that adsorption reached an equilibrium point shortly after five hours, suggests that the carbon needs to be reactivated after reaching the equilibrium in order to continue being effective or otherwise there should be a reapplication of fresh activated carbon (Marsh, 1989).

The range of ammonia concentration in the experimental tanks was between 0.01mg/l – 0.1mg/l and the temperature range was 21°C to 22°C. This was very close to the LC_{50} of ammonia for tilapia which is 0.02mg/l (Svobodova *et al*., 1993).

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References

Arcadio, P. S and Gregoria, A. S. 1996. Environmental Engineering a design approach, prentice- Hall of India private Ltd, New Delhi.

Bahl, B. S., A. Bahl and Tuli, G.D 2004. Essentials of Physical Chemistry. S. Chand & Company, New Delhi.

Coulson, J.M and Richardson, J.F. 2002. Chemical Engineering. Volume 2, 5th Edition, Butterworth-Heinemann, London.

Durborow, R. M., Crosby, D.M. and Brunson, M. W. 1997. Ammonia in fish ponds. SRAC Publication no. 463.

Kefi, A.S. 2008. Growth Performance and some aspects of reproduction of *Oreochromis macrochir* (Boulenger 1912) raised in semi- concrete ponds at varying stocking densities. Research and Technical report, National Aquaculture Research and Development Centre; 1: 26 – 36.

Marsh, H. 1989. Introduction to Carbon Science. Butter Worth and Company Ltd (Publishers). London.

Mattson, J.S. and Harry, B.M. 1971. Activated Carbon. Surface Chemistry and Adsorption from Solution. Marcel Dekker Inc. New York.

Peterson, J. O and Lee, F. G. 1971. Adsorption capacity estimation for activated carbon packed column. Water Research 5: 717 – 721.

Pillay, T. V. R. 1990. Aquaculture: Principles and Practices, Fishing News Books, Oxford.

Reynolds, T.D. and Richards, P.A. 1996. Unit operations and Processes in EnvironmentalEngineering 2nd ed. PWS Publishing Co.

Sawyer, C. N. and McCarty, P. L. 1978. Chemistry for environmental Engineering, 3rd Edition, McGraw-Hill, Inc.

Sincero Arcadio P. and Sincero Gregoria A. 1996. Environmental Engineering a design approach, prentice- Hall of India private Ltd, New Delhi.

Svobodova, Z., Lloyd, R. and Vykusova, J. M. B. 1993. Water quality and fish health. EIFAC Technical Paper No. 54. FAO, Rome.

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EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH OF JUVENILE *OREOCHROMIS SHIRANUS*

‡Matsimbe M.[1] and Kapute F.[2]

[1]NEPAD Regional Fish Node, Aquaculture and Fisheries Science Department, Bunda College of Agriculture, P.O. Box 219, Lilongwe, Malawi.
[2]Aquaculture and Fisheries Science Department, Bunda College of Agriculture, P.O. Box 219 Lilongwe, Malawi.
‡The author to whom correspondence should be addressed: msekiwa2@yahoo.com

Abstract

The experiment to investigate the effects of organic and inorganic fertilizers on primary production and growth of *Oreochromis shiranus* was conducted in fifteen $3m^2$ concrete tanks at the Aquaculture Fish Farm, Bunda College, University of Malawi. Fish with mean weight of 8 ± 1g were stocked at 30fish/m^2. There were five treatments (inorganic and feed, inorganic only, chicken manure and feed, chicken manure only, and feed only) which were replicated three times. After 84 days, fish raised on chicken manure and feed were significantly (P<0.05) larger and had higher net annual yields than the rest of the treatments. For treatments with either feed and fertilizer only, organic fertilizer had the highest fish growth rate and primary production. Significantly (P<0.05) higher amounts of chlorophyll *a* were produced in tanks fertilized with chicken manure. Overall, results obtained in this study, suggest that the use of chicken manure only, chicken manure and feed combination produces better results than inorganic fertilizer with either feed or no feed combination.

Keywords: Fertilization, organic fertilizer, inorganic fertilizer, *Oreochromis shiranus,* chlorophyll *a*

Introduction

Farmed fish obtain their food partly from natural production in the pond and partly as supplementary feed given by the farmer (Kang'ombe, 2004). Maize bran is used as a supplementary feed because it is the most potentially available ingredient for fish production and has been recommended as a pond input to Malawian fish farmers since the 1940s and is used by 90% of fish farmers in Malawi (Brummet, 1995).

For natural feed production, organic fertilizers are an efficient and economical means of increasing pond productivity. Organic fertilizers improve soil structure and fertility, encourage bacterial growths which in turn favour the production of zooplankton (FAO, 1997) which is nutritious and preferred food to many aquaculture species (Pillay, 1993). Inorganic fertilizers are also used in pond fertilization because of their quick nutrient release when applied, minimum mineral variability for fertilizer of the same type, easy distribution and that they can be stored for a long time. Although use of inorganic fertilizers usually result in high returns there is low consumption/use in Africa with a mean of 21kg/ha (Wallance and Knausenberger, 1997). Its use by farmers is constrained by its high cost (Miller, 2000).
The aim of study was to compare a) fish production from a commercial inorganic fertilizer, 23:21:0 + 4S with an organic fertilizer, chicken manure b) growth of *Oreochromis shiranus* and primary production in concrete fish tanks fertilized with organic and inorganic fertilizers.

Materials and methods

Study area

The study was conducted at Bunda College of Agriculture fish farm in Lilongwe, Malawi for three months from February to April, 2008.

Experimental layout and design

Thirty (30) fingerlings of *O. shiranus* with a mean weight of 8±1g were stocked in each of the 15 concrete tanks of approximately $3m^3$. The tanks were prepared by laying 10cm clay-loam soil at the bottom to act as a substrate for primary production and to simulate an earthen pond. The tanks were filled with water from the nearby dam. An initial pond fertilization using both types of fertilizers was done. Organic fertilizers were applied two weeks before stocking. Inorganic fertilizers were applied a week before stocking. The initial fertilization was done to ensure that production of plankton had occurred before the fish were stocked. The initial pond fertilization rates were 50kg/ha for inorganic fertilizer and 500 kg/ha for organic fertilizer. The fertilization rates were adjusted according to the water quality parameters.

The experiment was laid out in a Completely Randomized Design (CRD) with five treatments , replicated three replicates. First treatment was inorganic fertilizers plus feed, treatment two was inorganic fertilizers only, treatment three had organic fertilizers and feed, treatment four had organic fertilizers only and the fifth treatment had feed only.

Inorganic fertilizers were applied by broadcasting the feed on the water surface while organic fertilizers were soaked before application to reduce the amount of suspended solids and time of suspension on the water sur-

face. Fish were fed a diet of 30% crude protein feed that was formulated from maize bran, soybean, mineral and vitamin premix. Feeding was done twice a day at 08h:00 and 14h:00 at 2% per day.

Fish sampling and data collection

Twenty fish (20) fish were sampled per tank. Data on fish body weight (g), standard and total length (mm) was collected every fortnight using an electronic weighing balance and a measuring board. Quantity of feed was adjusted during every sampling time. At the end of the experiment, the tanks were drained and the fish were weighed, counted and measured.

Water quality parameters pH, temperature and turbidity were measured twice daily at 07h:00 and 14h:00 using a pH and temperature meter and secchi disk respectively. Dissolved oxygen, ammonia and chlorophyll *a* were measured weekly using a titration method.

Data analysis

Data was analyzed using analysis of variance (ANOVA) using a general linear model (GLM) with repeated measurements of weight over time. One-way ANOVA analysis was also performed for each time for weight. Means of treatments were separated using Duncan's multiple range test (DMRT) test at 0.05 level of significance. Specific growth rate (SGR) and Fulton's condition factor were computed using formulae described by De Silva (1995) and Kang'ombe (2004) respectively. Gross yield, net yield and survival of fish were computed as shown below:

- Gross yield of fish/ha = Harvested fish (kg) / unit area (ha)
- Net yield of fish/ha = (harvested fish weight kg – initial weight kg)/ unit area (ha)
- Survival Rate (%) = (initial number of fish – (number of harvested fish– initial number of fish) * 100

Results

Growth performance indices

Lower fish growth rate was observed in TRT2 than the rest of the treatments where there was an increase in weight by at least 1g every fortnight. However, all the mean weight gains between treatments with time were significantly different (P<0.05). TRT 3 (Organic fertilizers and feed) had significantly higher final mean weight (18.96g) than TRT 1 (inorganic plus feed, 16.18g), TRT 4 (organic only,15.68g), TRT 5 (feed only, 15.96g) and TRT 2 (inorganic fertilizer only, 9.45g) as shown in Figure 1 and Table 1.

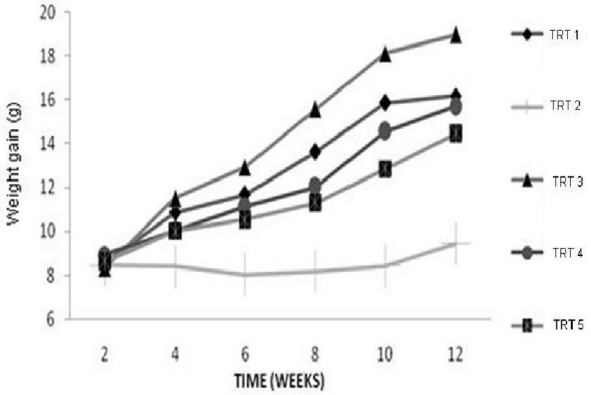

Figure 1: Mean weekly weight gain of *Oreochromis shiranus* grown in concrete tanks under different fertilization regime for 84 days. TRT 1 = Inorganic fertilizers plus feed, TRT 2 = Organic fertilizers only, TRT 3 = Organic fertilizers plus feed, TRT 4 = Organic fertilizer only and TRT 5 = Feed only.

Interaction effects of fertilizers and feed were also observed. For instance, fish in TRT1 (inorganic fertilizer plus feed) recorded 16.18g and TRT2 (inorganic fertilizer only) recorded 9.45g only as the final mean weight. Similary, a combination of organic fertilizer and feed (TRT3) resulted into a higher final mean weight(16.18g) while organic fertilizer only (TRT 4) resulted in mean fish weight of 15.68g.

TRT3 which had the highest final mean weight also showed highest growth rate(127.7%), mean daily weight gain (0.127g), gross yield (4234 kg/ha/year) and net yield (2375.15 kg/ha/year) as shown in Table 2. The opposite was observed in TRT2 which had the lowest values.

Table 1: Growth parameters of *Oreochromis shiranus* grown in concrete tanks under different fertilization regime for 84 days

	*TRT1	TRT2	TRT3	TRT4	TRT5
Initial mean weight (g)	8.69 ± 0.21^{a}	8.45 ± 0.24^{a}	8.33 ± 0.24^{a}	8.93 ± 0.24^{a}	8.61 ± 0.25^{a}
Final mean weight (g)	16.18 ± 0.38^{a}	9.45 ± 0.26^{b}	18.96 ± 0.47^{c}	15.68 ± 0.47^{d}	15.96 ± 2.38^{d}
Mean weight gain (%)	89.467^{a}	11.938^{b}	127.748^{c}	75.506^{d}	67.867^{d}
Mean daily weight gain(g)	0.091^{a}	0.012^{b}	0.127^{c}	0.080^{d}	0.070^{d}
SGR (% day^{-1})	0.76077^{a}	0.13425^{b}	0.97984	0.66965^{d}	0.61667^{d}

Values with same superscripts in a row are not significantly different (P>0.05), *TRT 1 = Inorganic fertilizers plus feed, TRT 2 = Organic fertilizers only, TRT 3 = Organic fertilizers plus feed, TRT 4 = Organic fertilizer only and TRT 5 = Feed only.

Fish survival and condition factor

As shown in Table 2, TRT3 had the highest survival rate of 97% seconded by organic and feed which had a survival rate of 94%. There was better fish survival for TRT5 treatment (92%). Low survival rates were observed TRT2 and TRT4 only which had 85% and 89% respectively. However, there were no significant differences (P<0.05) in the initial fish's condition between treatments. This was also true for the final health condition of the fish. However, differences were observed between initial and final conditions for individual treatments (Table 2).

Table 2: Yield and Fulton's condition factor of *Oreochromis shiranus* grown in concrete tanks under different fertilzation regime for 84 days.

	TRT1	TRT2	TRT3	TRT4	TRT5
Gross fish yield (Kg/ha/84 days)	1078.91	630.33	1264.00	1045.33	963.56
Gross fish yield (kg/ha/year)	3614.35	2111.62	4234.40	3501.87	3227.91
Net fish yield (kg/ha/84 days)	509.47	55.89	709.00	449.72	389.56
Net fish yield (kg/ha/year)	1706.71	187.23	2375.15	1506.57	1305.01
Survival rate (%)	97.778	85.556	94.444	88.889	92.222
Initial condition	0.003131[a]	0.0034[a]	0.003114[a]	0.003049[a]	0.003071[a]
Final condition	0.003374[a]	0.003022[a]	0.004252[a]	0.003317[a]	0.003463[a]

Values with same superscripts in a row are not significantly different (P>0.05). TRT 1 = Inorganic fertilizers plus feed, TRT 2 = Organic fertilizers only, TRT 3 = Organic fertilizers plus feed, TRT 4 = Organic fertilizer only and TRT 5 = Feed only.

Water quality

Temperature and Chlorophyl *a*

There was significant differences in chlorophyll *a* production in combined treatments of organic fertilizer plus feed and inorganic fertilizers and feed (P<0.05) compared to uncombined treatments of organic fertilizer only, inorganic fertilizer only and feed only. Temperature was was not significantlt different (P>0.05) in all the five treatments. (Table 3).

Table 3: Values (±SD) of temperature and chlorophyll a in concrete tanks under different fertilization regime for 84 days.
Dissolved oxygen, Ammonia and Turbidity

Temperature (^{0}c)		pH		chl *a* (µg/l)
07h:00	14h:00	07h:00	14h:00	
22.4085±2.24[a]	27.6158±19.69[a]	8.2714±0.28	8.1486±0.31	50.4688±12.18[a]
22.5964±2.21[a]	25.7280±1.79[a]	8.0547±0.10[a]	8.7389±0.14[a]	49.2072±9.81[a]
22.6707±2.19[a]	25.8772±1.81[a]	8.0597±0.18[a]	8.2973±0.29[ab]	67.3892±27.75[b]
22.5061±2.20[a]	25.6912±1.83[a]	8.1873±19[b]	8.38±0.19[b]	61.8332±11.38[b]
22.4637±2.80[a]	25.74±1.83[a]	8.1698±14[b]	8.4889±0.20[b]	59.8692±13.38[b]

Values with the same superscript in a column were not significantly different (P>0.05). TRT 1 = Inorganic fertilizers plus feed, TRT 2 = Organic fertilizers only, TRT 3 = Organic fertilizers plus feed, TRT 4 = Organic fertilizer only and TRT 5 = Feed only.

There were no significant differences (P>0.05) in the mean dissolved oxygen levels in all the treatments. Ammonia levels were significantly high TRT 1 (organic fertilizers plus feed) and TRT 3 (organic fertilizers only) compared to treatments with inorganic fertilizers and feed only; TRT 2 (Inorganic plus Feed), TRT 4 (feed only.) and TRT 5 (Inorganic only). Turbidity was high in TRT3 and low in TRT2. In terms of turbidity TRT1, TRT4 and TRT5 were not significantly different (P>0.05) (Table 5).

Table 5: Values of dissolved oxygen, ammonia and turbidity in concrete tanks under different fertilization regime for 84 days

	Dissolved Oxygen (mg/l)		Ammonia	Turbidity
	07h:00	14h:00	(mg/l)	(cm)
TRT 1	12.19[a]	12.29[a]	0.289[a]	21±0.7[a]
TRT 2	12.40[a]	12.56[a]	0.200[b]	28±0.3[b]
TRT 3	12.08[a]	12.10[a]	0.328[a]	18.2±0.9[c]
TRT 4	12.69[a]	12.66[a]	0.220[b]	22±0.9[a]
TRT 5	12.85[a]	12.83[a]	0.250[c]	20±0.8[a]

Values with same superscripts in a row are not significantly different (P>0.05). TRT 1 = Inorganic fertilizers plus feed, TRT 2 = Organic fertilizers only, TRT 3 = Organic fertilizers plus feed, TRT 4 = Organic fertilizer only and TRT 5 = Feed only.

Discussion

Fish Growth performance

Fish in treatments with organic fertilizers had growth rates than fish in the other treatments. Similary, Kang'ombe *et al.* (2006) reported that fish in ponds fertilized with chicken manure grew significantly better compared to cattle and pig manure. Chicken manure has high levels of nitrogen, phosphorous and potassium; 1.23, 1.39, 0.61, respectively (Kang'ombe *et al.*, 2006).

Feeding also contributed significantly to the growth of *Oreochromis shiranus* where fertilization was involved with the best performance for chicken manure. It was observed that single treatments (organic, inorganic and feeding only) did not result into the optimum growth rates of *Oreochromis shiranus*. Although this was the case, each treatment had an effect on fish growth. For instance the control treatment (feed only) resulted in addition of 2g weight after two weeks. The treatment where organic fertilizer only was applied produced superior results to feeding only.

At the end of the experiment the highest fish growth performance was noticed in the treatment of a combination of organic fertilizer and feeding seconded by a combination of inorganic fertilizer and feeding. Hence, combined treatments had better results.

Organic fertilizers treatments had higher yields, because organic fertilizers serve as direct food to invertabrates, fish food organisms and fish or decompose releasing nutrients that stimulate plankton growth. organic fertilizers are efficient in increasing the abundace of zooplankton andbenthic organisms (Boyd, 1990).

Interms of single treatments, organic fertilizer produced better results compared to inorganic ferilizer. There are several factors that could have been the possible causes: firstly, the inorganic fertilizer used for this investigation (23:21:0 + 4S) had higher nitrogen levels responsible for primary production. However, inorganic nitrogen quickly declines when applied in water (Boyd, 1990) due to several factors which include plant absorption, volatilization which could possibly be the major cause of nitrogen loss from ponds where afternoon pH values are high (Boyd, 1990). Secondly, the inorganic fertilizer used also had high phosphorous which is likely to be absorded by the mud in the aerated tanks which is also a limiting factor also recognised in Boyd (1990).

Similarly, good condition factors were recorded in all treatments except for inorganic fertilizer only pond treatment which may have decreased due to inadequate natural feed production levels.

In terms of fish growth and chlorophyll *a* production, a direct relationship was observed. Organic fertilizer and feed treatment had the highest fish growth rates than the rest which is also the case interms of chlorophyll a production. This observation is supported by Knud-Hansen (1998) that there is a strong positive relationship between Net algal Productivity (NAP) and the Net Fish Yield (NFY) for fish whose diet consists of natural produced food. The results also show that the treatments with feed combined with fertilization also had high fish growth rates and chlorophyll *a* production than single treatments.

Water quality

The minimum level of chlorophyll *a* that was produced was 49.21 µg/l and the highest levels were over 67.39µg/l on average. Chicken manure and feeding treatment had the highest chlorophyll *a* production. In a study by Kang'ombe *et al.* (2006) chicken manure also had significantly high chlorophyl *a* levels.

The treatments with inorganic fertilizer did not differ significantly (P<0.05) because the inorganic fertilizer-had added the same quantities of nutrients and had the same effect on water quality. Therefore, there were limited sources to variation in chlorophyll *a* production. The same applies for treatments which had organic fertilizer. It is well established that phytoplankton productivity is positively correlated with nutrient concentrations (Boyd, 1990).

Conclusion

High productivity levels (fish and primary production) were observed in treatments which had both fertilization and feeding. However, treatment TRT3 (organic fertilizer plus feed) had the higher productivity than treatment TRT1 (inorganic fertilizer plus feed). For uncombined treatments, organic fertilizer had the highest fish growth rates, seconded by feed only and inorganic fertilizer had the poorest growth rates. Although the combination of organic fertilizer plus feed gave the superior results, it is not yet practically feasible for

local fish farmers to formulate or purchase high protein feed. Therefore, the high fish yield returns due to use of chicken manure gives an opportunity to Malawian fish farmers as the poultry population was estimated at 11.5 million (83% chickens) in 1998 (Kang'ombe *et al.*, 2006). According to Safalaoh (1997), chickens are widely and equitably distributed among households of poor and marginalized people in Malawi. This means chicken manure could be one of the best and reliable sources of manure that fish farmers can easily access and utilize.

In general, the results suggest that supplementary feeding and pond fertilization is a necessicity in aquaculture although there were differences in the effects depending on type of pond fertilization.

References

Boyd, C.E. 1990. *Water quality in ponds for aquaculture*, Alabama Agricultural Experiment Station, Auburn University, Alabama.

Brummet, R.E. 1995. *Aquaculture for African smallholders*, ICLARM technical report 46, Germany.

De Silva, S.S. 1995. *Fish Nutrition in aquaculture*, Chapman and Hall, 2-6 Boundary Row, London.

FAO,1997. Simple methods for aquaculture, Training Series 21/1. FAO Rome, Italy.

Kang'ombe, J. 2004. Development of feeding protocols for *Tilapia rendalli* in Malawi reared in semi-intensive culture system, PhD Thesis, Memorial university of Newfoundland and Labrador, Canada

Kang'ombe, J., Brown J.A. and Halfyard, L.C. 2006. Effect of using different types of organic animal manure on plankton abundance and on growth and survival of *Tilapia rendalli* (Boulenger) in ponds. Aquaculture research, 37, 1360-1371.

Knud-Hansen, C.F. 1998. *Ecological approach and practical application*, Oregon State University, Corvallis, Oregon.

Miller, M. 2000. *Fertilization and feeding practices in warm water pond fish culture in Africa*, http://en.wikipedia.org/wiki/Tilapia_in_aquaculture

Pillay, T.V.R. 1993. *Aquaculture principles and practices*, University press, Cambridge.

Safalaoh, A. 1997. *Characteristics of indigenous chickens in Malawi*, Animal Genetic Resource Information 22, 61-69.

Wallance, K. and Knausenberger, M. 1997. *Inorganic fertilizer use in Africa: Environmental and economic dimensions*, environmental and natural resources policy and training (EPAT) project, Virginia, USA.

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GROWTH, FEED UTILIZATION AND SURVIVAL OF AFRICAN CATFISH, *CLARIAS GARIEPINUS* (BURCHELL, 1822)

Silli L.M. and ‡Kang'ombe J.

5Aquaculture and Fisheries Science Department, University of Malawi, Bunda College of Agriculture P.O Box 219, Lilongwe, Malawi.
‡The author to whom correspondence should be addressed: jeremiah_kangombe@yahoo.com

Abstract
An indoor experiment was carried out at Bunda College Aquaculture farm, University of Malawi in 200 L tanks to determine effects of vitamin supplementation on growth, feed utilization and survival of catfish, *Clarias gariepinus*. The experiment was conducted for 98 days using catfish of an average weight of 32g stocked in 12 tanks with 15 fish in each tank. The fish were fed diets having different vitamin inclusion levels ranging from 0.5% to 2.0% as treatments. At the end of the experiment, there were no significant differences on growth responses, feed utilization and water quality parameters. However, survival rates and daily feed intake differed significantly ($P<0.05$) among treatments. The treatment in which fish were given of 2.0% vitamin inclusion level had average final weights of 48.28 ± 2.06g and had the highest survival rate of 64.4% ($P<0.05$). The 0.5% vitamin inclusion level produced average final weights of 43.47±2.85g. The fish efficiently utilized the feed that was given as their feed conversion ratios were within the acceptable ranges for catfish. No signs of nutritional deficiency were noticed during the experiment except for bruises on the bodies of some fish that resulted in some mortalities. Results of the experiment suggest that vitamins are important for growth, health, survival and general maintenance of metabolism in fish.

Key words: *Clarias gariepinus*, Vitamin supplementation, Growth, Feed utilization

Introduction

In Malawi fish supply from the lake and other natural water bodies is dramatically decreasing. However, the human population is increasing creating a greater demand for fish that serve as a main inexpensive source of protein contributing about 60-70% of the animal protein (ICLARM and GTZ 1991). Therefore, increase in fish production is needed to meet the high demand of fish, and this calls for intensive fish production which is characterized by high stocking densities and relies much on external input i.e. supplementation of formulated diets so as to achieve high yields of desirable and marketable fish (Shepherd and Bromage, 1988).

Clarias gariepinus, known as the African catfish, is a recent addition to aquaculture in Africa which has largely been dominated by tilapia. Though its potential for farming has been demonstrated, its culture seems to be restricted to the Central African countries, the Ivory Coast and, on experimental scale, Egypt (Huet, 1994). Some work on *C. gariepinus* has also been performed in South Africa (Hecht and de Moor, no date). *Clarias gariepinus* can best be described as an omnivore, often feeding on vegetable matter, aquatic invertebrates, small fish, detritus, *etc*. The vitamin nutrition of catfish has been the subject of numerous research reports (NRC, 1993; Al-Hafedh and Alli, 2004)) which has culminated in the development of a vitamin premix that is used to provide supplemental vitamins in commercial catfish feeds. The vitamin premixes contain all essential vitamins in sufficient quantities to ensure optimum fish growth and health, and to compensate for losses during feed manufacturing and storage (Halver, 1972). The composition of catfish vitamin premixes has been based on vitamin requirements determined with small, rapidly growing catfish raised under laboratory conditions. These values have been considered sufficient to meet the needs of fish raised under captivity (Lovell, 1989; Stickney, 1990).

However, vitamin requirements may be affected by several factors including fish size, fish health, and other environmental conditions like temperature, pH, salinity, dissolved oxygen, ammonia content, among others (Huet, 1994). In most wild fishes, including catfish, vitamin deficiencies are not specific and rarely occur because fish growth in the wild is relatively slow and natural foods seem to contain adequate amounts of all vitamins to meet the needs of the fish.

On the other hand, vitamin deficiencies are more likely to occur in cultured fish because manufactured feeds promote fast growth, and therefore vitamin requirements are said to be higher (Robinson *et ai.*, 2003). However, signs of vitamin deficiency are uncommon in cultured fish because it is assumed that commercial feeds contain a vitamin supplement that is generally more than adequate to meet the fish's needs. Therefore, determination of the effects of vitamin supplementation and the possible deficiency signs that are likely to occur in cultured catfish, *C. gariepinus* is of great importance as it may assist fish farmers in formulating diets for their fish (Robinson *et al.,* 2003). This study was therefore conducted to determine the effect of vitamin supplementation on the growth and feed utilization of catfish, *C. gariepinus (*Burchell, 1822).

Materials and methods

Experimental set up

The experiment was carried out at Bunda Aquaculture farm, Malawi, in twelve 200 L plastic tanks, each of which was stocked with 15 fish of an average weight of 32g. The fish for the experiment were collected from the hatchery at the Bunda Aquaculture farm. A completely randomized design (CRD) was used in the experiment to assign the treatments and stocking fish in tanks. Four dietary treatments were assayed, each of which was replicated three times. The treatments were as follows: Treatment 1: 0.5% vitamin level; Treatment 2: 1.0% vitamin level; Treatment 3: 1.5% vitamin level; and Treatment 4: 2.0% vitamin level.

Feed formulation and analysis

The feeds were formulated to contain 30% crude protein using Pierson's Square method where ingredients were grouped into two groups of proteins and energy. These were calculated using a targeted protein level of 30% Crude protein and the ingredients were fish meal, soy bean meal, maize and rice bran, vitamin premix and mineral premix (Table 1).

Table 1: Feed ingredients inclusion levels (%) in the diets containing 30% crude protein having varying vitamin inclusion levels formulated for *Clarias gariepinus*.

Ingredient	Dietary vitamin inclusion levels			
	0.5%	1%	1.5%	2%
Fishmeal	21.2	21.1	21.0	20.8
Soy bean meal	21.2	21.1	21.0	20.8
Maize bran	28.0	27.9	27.8	27.7
Rice bran	28.0	27.9	27.8	27.7
Vitamin premix	0.5	1.0	1.5	2.0
Mineral premix	1.0	1.0	1.0	1.0
Total	99.9	100.0	100.1	100.0

Maize and rice bran were bought from local millers around the College's main farm, while soy beans were bought from the farm and the vitamin and mineral premixes were bought in Lilongwe city. The soy beans were then roasted and milled. These ingredients were mixed and pelleted. The pellets were then dried in an oven at 85°C for an hour after which they were put in paper bags covered by plastic paper, sealed and stored in a freezer ready to be fed to fish. The experiment was run for a period of 14 weeks (98 days), and the fish were fed twice a day at 09:00 hrs and 15:00 hrs at the rate of 5% body weight. Initially, the water supply for the tanks had to be checked to ensure that the water was free of pollutants, and that all the quality parameters are within the desired range. The key elements considered in the culture of catfish were dissolved oxygen (DO), ammonia, and nitrite because they are easily affected by biological processes.

Growth, survival and feed utilization

Growth was monitored fortnightly by measuring the body weight, standard and total lengths of fish for each treatment. Before taking these measurements, fish were anaesthetized using benzocaine to minimise handling stress. Then feed conversion ratio (FCR), survival rate (%) and specific growth rate (SGR, %/day) were calculated, using the formulae:

FCR = total weight of dry feed offered (g)/ total live wt. gained by fish (g),

SGR (%/day) = $(In\ W_t - In\ W_0)/T * 100$, where *In* = natural logarithm, W_t and W_0 = final & initial weight, respectively, and T = time in days;

Survival (%) = $(N_t/N_0)*100$, where N_t = number of survivors at time t. N_0 = number of fish at time 0 (at stocking).

Deficiency signs observations

During every fortnight sampling, the fish were closely observed for any possible abnormalities and nutritional deficiency signs.

Water quality data

Water quality parameters like pH, DO and temperature were recorded twice daily in the morning at 08:00 hrs and afternoon at 16:00 hrs. Ammonia content was monitored on weekly basis. These were taken by using a multipurpose water checker. The tanks were cleaned and filled with fresh water once a week.

Statistical analysis

Growth, feed conversion, survival, and feed intake were analyzed using a Statistical Package for Social Scientists (SPSS 11.0 for windows). This analysis was done at a probability level of 5% using a One-way Analysis of Variance (ANOVA). Where differences appeared to be significant, Duncan's Multiple Range Test was used to separate means.

Results

Effect of vitamin supplementation on growth of catfish

The initial weights of the fish did not differ significantly ($P>0.05$) at the beginning of the experiment. The fish did not show any significant differences in growth parameters (Figure 1).

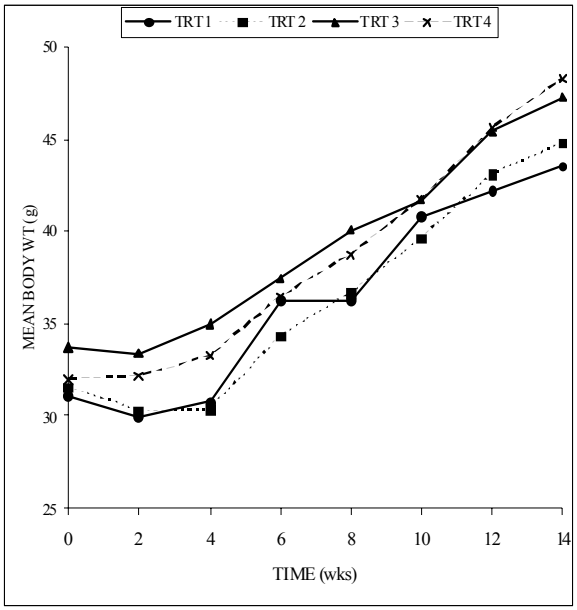

Figure 1: Mean body weight of *Clarias gariepinus* reared in tanks fed diets varying vitamin inclusion levels for 98 days.

However, the fish in treatment 4 which had 2.0% vitamin inclusion level had higher weight gains seconded by those in treatment 3 with 1.5% vitamin inclusion level and those with 1% inclusion level and lastly those in treatment 1 with 0.5% vitamin inclusion level. The specific growth rates were also higher in treatment 4 producing 0.41 %/day (Table 2).

Effect of vitamin supplementation on feed utilization and survival

The total feed offered through out the experiment did notdiffer significantly (P>0.05) among the treatments. However, the feed offered per day differed significantly (P<0.05) among the treatments. The fish in treatment 2 with 1% vitamin inclusion level utilized the feed more efficiently resulting in FCR of 1.37 followed by the fish in treatments 4, 1 and 3 producing FCRs of 1.47, 1.57 and 2.0, respectively (Table 2).

Table 2: Initial weight, final weight, weight gain, feed amount .day, feed conversion ratio (FCR) and specific growth rate (SGR) and survival of *Clarias gariepinus* reared in tanks fed diets varying in vitamin inclusion levels (Mean ± Se).

Parameter	Dietary Vitamins			
	0.5%	1%	1.5%	2.%
Initial Weight (g)	31.067 ± 0.888	31.571 ± 0.965	33.736± 0.930	31.942 ± 0.979
Final weight (g)	43.478 ± 2.847	44.757 ± 3.192	47.242± 2.128	48.279 ± 2.062
Weight gain (g)	12.411 ± 1.688	13.186 ± 1.852	13.506± 2.338	16.337 ± 3.268
Feed amnt/dy (g)	17.63 ± 1.19^{a}	18.04 ± 1.37^{a}	23.49 ± 0.93^{b}	22.19 ± 0.39^{b}
FCR	1.57 ± 061	1.37 ± 0.48	2.00 ± 0.65	1.47 ± 0.58
SGR (%/day)	0.34 ± 0.054	0.36 ± 0.045	0.34 ± 0.063	0.42 ± 0.074

Means in the same row with different superscripts are significantly different (P<0.05).

Fish in treatment 4 with 2% vitamin inclusion had significantly (P<0.05) higher survival rates (64.4%) and followed by fish in treatments 3, 2 and 1 having 57.8%, 51.1% and 40% survival rates, respectively. No deficiency signs were noticed during the whole experimental period. However, it was observed that a lot of fish in treatment 1 (0.5% vitamin) died during the study. Out of the 45 fish stocked at the beginning of the experiment, only 18 survived representing a survival rate of 40%. While those from treatment 4 (2 % vitamin) had the highest number of survivals (29) representing a survival rate of 64.4% (Figure 2).

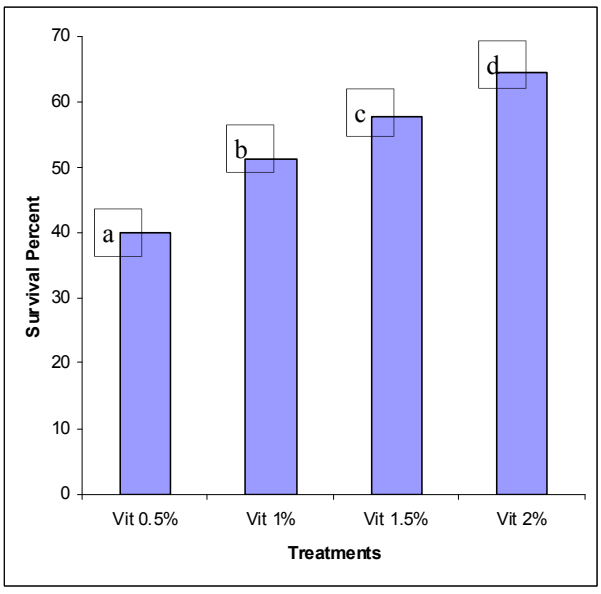

Figure 2: Survival (%) of *Clarias gariepinus* reared in tanks fed diets varying vitamin inclusion levels for 98 days. Different letters indicate significant differences (P<0.05).

Water quality monitoring

All the water quality parameters, after analysis, were found not to differ significantly (P>0.05). The best part of it was that they were found to be within the normal tolerance range for normal growth, survival, maintenance and general metabolism for catfish (Table 3).

Table 3: Water quality parameters (pH, dissolved oxygen-DO, temperature-Temp and ammonia) monitored through out the experimental period (Mean± SE).

Parameter	Dietary Vitamins			
	0.5%	1.0%	1.5%	2.0%
pH –am	6.14 ± 0.23	6.13 ± 0.26	6.15 ± 0.24	6.10 ± 0.32
pH – pm	6.02 ± 0.19	6.01 ± 0.23	6.10 ± 0.32	6.04 ± 0.29
DO (mg/L)-am	8.05 ± 0.45	7.71 ± 0.54	7.95 ± 0.39	7.96 ± 0.37
DO (mg/L)-pm	8.04 ± 0.69	7.67 ± 0.76	7.92 ± 0.48	7.92 ± 0.45
Temp (° C)- am	22.97 ± 0.46	22.83 ± 0.44	22.58 ± 0.32	22.73 ± 0.45
Temp(° C)- pm	23.48 ± 0.48	23.46 ± 0.48	23.54 ± 0.43	23.48 ± 0.56
Ammonia (mg/L)	0.38 ± 0.16	0.34 ± 0.22	0.33 ± 0.22	0.33 ± 0.17

Treatment means not significantly different (P>0.05)

Discussion

The results showed that there were no significant differences among the treatments as portrayed by the trend of the growth curves and other parameters except the daily feed intake. However, Fagbenro (1999) in his study on equi-protein replacement of soy bean meal with winged bean meals in diets for African catfish, *Clarias gariepinus,* reported similar growth responses when catfish of 30g initial weight were fed winged bean seed meal as a protein feed stuff in fish meal free diets. This also agrees with what Webster, *et al.* (1995) who reported similar growth responses in channel catfish (*Ictalurus panctatus*) fed with high levels of soy bean meal in fish meal free diets and a control diet containing fish meal as the sole protein source. Nonetheless, these findings were in contrast with the findings of Moshen and Lovell (1990) who reported reduced growth in channel catfish fed with high soy bean inclusion in fishmeal free diets.

However, the FCRs obtained in the present experiment are not far from those commonly reported for catfish. Lovell (1988) reported that catfish is among the fish species that covert feed more efficiently and can achieve feed conversion ratios of 1.4-1.5 when fed to satiation at 2.5% body weight. Al-Hafedh and Alli (2004) in their experiment on the effect of feeding on survival, cannibalism, growth and feed conversion of *Clarias gariepinus* fed daily on 0%, 2%, 4%, 6%, 8% and 10% body weight, found that the feed conversion ratios were significantly better in the feeding rates between 2-4% body weight with FCRs ranging from 1.14 -1.13 than higher feeding rates of 6%, 8% and 10% body weight producing FCRs of 1.37, 2.18, 2.98, respectively.FCRs for commercial catfish feeds in Thailand usually ranged from 1.5 – 2.0 (Jantrarotai and Jantrarotai, 1993). Several researchers have reported higher values than the FCR values observed in the present study. Lan (1999) observed FCRs of 3.2 when hybrid catfish were fed laboratory made feed containing various combinations of trash fish, fish meal, shrimp processing waste and rice bran. Little *et al.* (1994) reported FCR values of 4 when hybrid catfish were fed poultry waste. However, Li and Lovell (1984) observed relatively lower FCRs ranging from 1.25 – 1.30 when fish were fed similar commercial feeds in their experimental ponds.

On the other hand, Lovell (1988) reported that as fish size increases, feed consumption as a percentage of body weight decreases and feed conversion increases. In his study conducted at Auburn University during the summer months when the temperature is rather constant, small catfish (45g initial weight) consumed more feed, grew faster and converted feed better than larger fish (150-550g initial weight). He concluded that feed consumption increases with water temperature until the temperature of around 32^{o}C is reached and consumption begins to decrease. Failure to detect any gross abnormalities or deficiency signs was not particularly surprising in this present study. Other researchers working with a variety of fish species had difficulties in inducing a vitamin E deficiency to manifest gross deficiency signs. Recently, Baker and Davies (1996) failed to observe pathologies or reduced growth while feeding African catfish, *Clarias gariepinus,* a diet with as littleas 2.15mg alpha-tocopherol, a compound that has the highest vitamin E activity for 10weeks.

Statistical differences were not detected during the analysis in the vitamin levels. This could be attributed to narrow range of vitamin supplementation. The requirement estimates for vitamin supplementation have been reported for channel catfish (Wilson *et al.,* 1984) and for rainbow trout, *Onchorhynchus mykiss* (Cowey *et al*., 1983) based on lipid peroxidation of hepatic microsomes. But in this present experiment, it was not possible to use the lipid peroxidation as an indicator of dietary vitamin requirement because of the narrow range of supplementation levels used. The water quality parameters did not affect either the growth or feed consumption and consequently feed utilization efficiency. The parameters did not differ significantly and were within the normal tolerance ranges for growth and survival of catfish (Boyd, 1990).

The values recorded were found to agree with the findings of Stickney (1994). The author further reported that prolonged exposure of catfish to non-optimal conditions may not lead to death but could result in reduced growth, impaired reproduction performance, or increased susceptibility to diseases. In conclusion, the results of the experiment indicated that vitamins are essential for catfish. The supplemented vitamin levels did not to significantly affect the growth, and feed utilization but significantly influenced survival. This could be attributed to the narrow range of the inclusion level. The difference between the treatments which was 0.5% could be considered small to detect significant differences on growth among treatments. However, it can be recommended that further studies be conducted where diets deficient in a particular vitamin could be given to catfish fingerlings and observe their growth, feed utili-

zation and deficiency signs. The studies can also include some histopathological examination of liver tissues of catfish fed diets deficient in a particular vitamin to find out if the fish would show abnormalities suggesting nutritional disorder.

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References

Al-Hafedh, Y.S. and S.A. Alli. 2004. Effect of feeding, cannibalism, growth & feed conversion of African catfish *clarias gariepinus* in concrete tanks. Food Resources Division. Natural Resources and Environmental Research Institute. King Abdulaziz City of Science & technology. Riyadh, Saudi Arabia.

Baker, R.T.M. and S. J. Davies. 1996. Changes in tissue and alpha-tocopherol status and degree of lipid peroxidation with varying alpha-tocopherol acetate inclusion in diets for the African catfish *Clarias gariepinus*. Aquaculture Nutrition 2, 71-79.

Boyd, C.E. 1990. Water quality in ponds for Aquaculture. Alabama Agricultural Experiment Station. Auburn University, Alabama.

Cowey, C.B., Andron J.W., Youngson A. and D. Knox. 1983. The vitamin E requirement of rainbow trout (*Salmo gairdneri*) given diets containing polyunsaturated fatty acids derived from fish oils. *Aquaculture* 30, 85-93.

Fagbenro, O.A. 1999. Equi-protein replacement of soy bean meal with winged bean meals in diets for the African clariid catfish, *Clarias gariepinus*. Journal of Aquaculture Trop, 14, 93-99.

Halver, J.E. 1972. The vitamins. In fish nutrition, edited by J.E. New York, Academic press, pp 29-103.

Hecht, T. and I. de Moor. no date. Small-scale aquaculture in Sub-Saharan Africa. Feeding and nutrition. Department of Ichthyology and Fisheries Science of Rhodes University, RSA. Retrieved14 September 2003 fromhttp://cdserver2. ru.ac.za/ cd/011120_1/Aqua/SSA/feed.htm.

Huet, M. 1994. Textbook of fish culture, Breeding & cultivation of fish. 2nd Ed. Fishing News Books. Oxford.

ICLARM & GTZ. 1991. The context of small-scale integrated agriculture-aquaculture systems in Africa: A case study of Malawi. ICLAM Stud. 18, 302p.

Jantrarotai, W and P. Jantrarotai. 1993. On farm feed preparation and feeding strategies for catfish and snakehead. In: Farm made aquafeeds (ed. by M. B.New, A.G.J. Tacon & I. Csavas), Proceedings of the FAO/AADCP Regional Expert Consultation on Farm Made Aquafeeds, 14-18 December 1992, Bangkok, Thailand, pp. 101-109.

Lan, M.L. 1999. Use of wastewater from Intensive hybrid catfish (*Clarias macrocephalaus* and *Clarias gariepinus*) pond culture as fertilizer for rice crop. MSc Thesis, Asian Institute of Technology, Bangkok, Thailand, 76 p.

Li, Y. and R.T. Lovell. 1984. Evaluated levels of dietary ascorbic acid increase immune responses in channel catfish. *Journal of Nutrition* 115, 123-131.

Little, D.C., Kaewpaitoon, K. and T. Haitook. 1994. The commercial use of chicken processing wastes to raose hybrid catdish (*Clarias gariepinus* x *Clarias macrocephalus)* in Thailand, Naga, The ICLARM Quarterly, 25-27.

Lovell, T. 1988. Use of soy bean products in diets for aquaculture species. Journal of Aquaculture products 2, 27-52.

Lovell, T. 1989. Nutrition & feeding of Fish. Van Nostrand Reinhold. New York.

Moshen, A.A. and R.T Lovell. 1990. Partial substitution of soy bean meal with animal protein sources in diets for catfish. Aquaculture Nutrition 90, 303-311.

National Research Council (NRC). 1993. Nutritional Requirements of Fish. National Academy Press. Washington, D.C., 114p.

Robinson, E.H., Li M.H. and D.F. Oberlie. 2003. Catfish vitamin nutrition. Thad CochranNational Warmwater Aquaculture Center, Mississippi State University, Stoneville. USA.

Shepherd, J. and N.R Bromage. 1988. What is Fish Farming? In shepherd Intensive Fish farming. Oxford BSP Professional Books. London.

Stickney, R.R. 1994. Principles of Aquaculture. University of Washington, School of Fisheries. John Wiley & Sons INC. New York.

Stickney, R.R. 1990 (Editor). Encyclopedia of Aquaculture. A Wiley-Interscience publication. John Wiley & Sons Inc. New York.

Webster, C.D., Tidwell J.H. Tui L.S. and D.H. Yancey. 1995. Use of soy bean meal as a partial or total substitution of fishmeal in diets for blue catfish, *Ictalurus furcatus.* Journal of aquatic living resource 8, 379-384.

Wilson, R.P., Bower P.R. and W.E. Poe. 1984. Dietary vitamin E requirement of channel catfish fingerling. Journal of Nutrition 114, 2053-2058.

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COMBINED EFFECT OF WATER TEMPERATURE AND SALINITY ON EGG INCUBATION PERIOD, HATCHING PERIOD AND EGG HATCHABILITY IN AFRICAN CATFISH *CLARIAS GARIEPINUS* (BURCHELL 1822)

Ssenfuma R[1]., ‡Kassam D[2]., Gondwe T.N[2]., Mtethiwa A. H[2]. and Sikawa D[2].

[1]Kyambogo University, P. O. Box 1 Kyambogo Uganda
[2]Aquaculture and Fisheries Science Department, Bunda College, University of Malawi, P.O. Box 219, Lilongwe, Malawi.
‡Author to whom correspondence should be addressed: dadeka@yahoo.com

Abstract
The study was undertaken to determine the combined effect of water temperature and salinity on egg incubation and hatching period; and egg hatchability. Fertilized eggs, from broodstock reared for commercial seed production, were incubated in 1000ml glass flasks and each flask was subjected to one of the three temperatures (25, 28, and 31°C) and one of the three salinities (0, 3 and 6ppt), totaling nine combinations, in triplicates. The results showed that both temperature and salinity accelerates egg incubation and hatching period of *C. gariepinus* eggs and the optimum temperature-salinity combination for egg incubation and hatching period was 31°C and 3ppt. Egg hatchability was higher in salty water than in freshwater and higher at high temperature than at low temperature and the best temperature-salinity combination for egg hatchability was 28°C and 3ppt. Such temperature-salinity combination is recommended for the improvement of catfish seed production which is key problem in catfish industry.

Key words; *Clarias gariepinus,* Egg incubation and hatching period, Egg hatchability, Temperature, Salinity

Introduction

The African catfish, *Clarius gariepinus*, is considered one of the most important tropical fish for aquaculture throughout Africa, Asia and Europe (Hocutt, 1989). Its broad geographical distribution is attributed to its biology, ecology and ability to tolerate physiologically adverse environmental conditions (Hecht and Appelbaum, 1988). It exhibits many qualities which makes it suitable for commercial culture. These include good growth characteristics i.e. reaching up to 1 kg in 8 months (Borode *et al.,* 2002), high disease resistance, high fecundity (Haylor, 1993), good survival in captivity and it is omnivorous; therefore it is valuable for aquaculture worldwide (Khwuanjai *et al.,* 1997). In Africa, however its full aquaculture potential has not yet been exploited. The main constraint facing its commercial culture in the sub-Saharan Africa has been the lack of fingerlings, both in terms of quantity and quality, for stocking purposes (Rasowo *et al*., 2007). This has been attributed to a number of factors such as its characteristic gonadal seasonal cycle i.e. gravid females may be found in freshwater from October (spring) until water temperatures drop in March/April (autumn) (Britz, 1991), lack of parental care, inability to spawn in captivity (Rasowo *et al*., 2007). Besides, African catfish fingerlings exhibit low survival in earthen ponds (De Graaf and Janssen, 1996). African catfish fingerlings are mainly produced through induced breeding techniques; but hatchability and survival of the fingerlings is generally very low amongst hatchery operators. It is apparent that management protocols covering egg production, incubation and hatching are lacking and may need enhancement to ensure sufficient production and supply of catfish seed.

Whereas several water quality parameters affect the survival, hatching duration and hatchability, temperature and salinity are the most important as far as African catfish fingerling production is concerned (Aktas, 2004). Abiotic factors including temperature, oxygen and salinity affect the physiology of both the incubated eggs and larvae. Subsequently, the growth and survival of fish that results from stressed/affected eggs are also affected (Holliday, 1969). The independent and interactive effects of water temperature and salinity are understood from fingerling to adult stages but not on the embryonic and larval stages.

However, Kokurewicz (1971) reported the effects of water temperature on the survival and hatching of fish embryos. Each fish species requires different temperature conditions for spawning, embryonic, larval, and juvenile development (Herzig and Winkler, 1986). Salinity on the other hand affects hatching rate, egg diameter, and has an important effect on egg survival in commercial hatcheries.

Whereas salinity and temperature operate in combination to affect the success of the incubated eggs, most studies have examined them independently. This study therefore investigated the combined effects of the two parameters on early stages of *C. gariepinus* bearing in mind that the optimal temperature and salinity combinations for egg incubation is species-specific (Preston, 1985). Therefore this study was carried out to establish the optimum combination of temperature and salinity which could be used as a method to improve survival and quality of embryos and larvae of *C. gariepinus* in hatcheries.

Methods and materials

Brood-stock management and hormonal treatment

The study was carried out at the National Aquaculture Center at Domasi, Zomba District, in Malawi. The timing was between September and December 2008, which is the natural breeding season of *C. gariepinus*.

The mature females and males of *C. gariepinus* broodfish were selected from a stock maintained for commercial breeding program at the National Aquaculture Center in Domasi, with individual weights ranging between 500 and 700g. All broodfish were selected using external morphological characteristics; female broodfish which were selected had soft and distended abdomen from which matured eggs, based on their greenish coloration and singular occurrence, were stripped by gentle application of pressure (Janssen, 1987). Male brood fish were only selected if they possessed elongated and reddish pointed urino-genital papillae. Fifteen females and 10 males were selected. Males and females were kept separately in concrete tanks measuring (10 x 8 x 1.2) m^3. The broodstock were acclimatized in their new environment (concrete tanks) for 7 days at mean temperature of 28 ± 2^oC and normal photoperiodic regimes with water pH around 7.1±0.1 The broodfish were fed on formulated pellets (35% crude protein) twice per day (7 am and 5 pm) at 5% of total fish biomass.

Prior to hormone injection, a total of four female broodfish and four male broodfish were randomly seined out from the tanks and kept singly in aerated 50L aquaria, with 25 litres of aerated water for 12 h. The randomly-selected females were measured in terms of weights and total lengths of 580, 660, 650 and 500g, and 47.5, 50.0, 49.5 and 58.0 cm, respectively, and males had weights and total lengths of 600, 650, 680 and 700g and 46.5, 40.0, 48.5 and 65.0 cm TL, respectively.

Broodfish were injected with ovaprim©, a synthetic analogue of gonadotropin releasing agent (Syndel Laboratories, Canada), between 6 and 7 pm. Ovaprim was administered in liquid form at 0.5 ml/kg body weight of female fish. Each male was injected with half of the dose of the female (Legendre, 1986; Haniffa and Sridhar, 2002). The injected fish were returned and kept separately into their respective 50L aquaria for 12h, and water temperature was maintained at 28^oC using thermostatically controlled water heaters.

Fertilization and preparation of test solutions

Ovulated females were stripped the following morning after injection at room temperature (25°C) to collect eggs. The ovulated eggs oozed out by slight thumb pressure onto the plastic bowl. The fish were stripped until traces of blood were observed which signified that the ovaries were empty. For male gametes, mature males were sacrificed (killed) and sperm sacs were collected, then incisions were made on the sperm sacs following Viveiros (2002). Milt was squeezed and spread over the eggs then mixed thoroughly with a soft clean feather. To this, 0.6% saline solution was added and further agitated for few seconds. Spermatozoa from one mature male were used to fertilize eggs stripped from three females while keeping the eggs from different females separately. The process from stripping to fertilization took three minutes to accomplish.To obtain the required salinities, for all the tests on salinity tolerance of fertilized eggs and yolk-sac larvae, three concentrations of the common salt, NaCl, (0, 3, and 6 g/l) were prepared by dissolving these three amounts of salt in a liter of freshwater each. The mixture was tested with a salinometer, to confirm the salinities of the test solutions.

Incubation period, hatching period and hatching rate (hatchability):

At incubation, a 3x3 factorial design was used where three temperatures (25, 28, and 31ºC) and three salinities (0, 3 and 6ppt) levels each with three replicates were used. Immediately after fertilization, eggs were transferred into 1000ml-capacity beakers (100 eggs per each beaker), beakers were filled to 800ml mark with the test media. Aerators were placed in each water bath and in each beaker to ensure temperature homogeneity and oxygen supply respectively. All unfertilized eggs which turned white (i.e. 14h post-fertilization) were removed from each beaker using a pipette, put into a Petri-dish and counted twice in portions using the naked eyes and their numbers were subtracted from the total number of incubated eggs in each beaker to get the total number of fertilized eggs. A stereo-loupe microscope connected to a video screen was then used to counter check the counts done by the naked eye. The incubation period is defined as the time from the placement of eggs to the time of the first hatch (Molokwu and Okpokwasili, 2002) and the hatching period began from the time of placement and ended when 50% eggs hatched (Aktas, 2004). At the end of hatching all hatched larvae, dead larvae and non hatched eggs were counted and the hatching rates (HR) or hatchability was determined by the formula below according to Radonic et al. (2007)

$$HR = \frac{\text{hatched larvae}}{\text{Hatched larvae + dead larvae + non hatched eggs}} * 100$$

Other water quality parameters

Water parameters were monitored on a daily basis. Temperature was measured using thermometer, pH was measured using Hanna Hep pH meter, dissolved oxygen was measured with digital dissolved oxygen concentration meter, optimum oxygen level was maintained with RESUN LP- 100 low noise air – pump, and salinity was monitored with portable refractometer salinometer.

Data analysis

The effect of temperature and salinity on incubation period, hatching period and egg hatchability, were analyzed using two-way analysis of variance after normali-

ty tests for ANOVA were done. When means were found to be significant (P<0.05), multiple comparisons among means were done using Scheffe's test. Both ANOVA and Scheffe's tests were done using SAS.

Results

Effect of temperature on egg incubation period, hatching period and hatchability

Egg incubation and hatching period decreased progressively with increasing temperature from 25 to 31°C at all the three incubation salinities (Table 1). There were significant differences (P<0.05) among treatments for each salinity. Egg hatchability was highest at 28°C at all the three incubation salinities. There was no significant differences in hatchability (P>0.05) at all the three incubation temperature when eggs were incubated at 3ppt but at 0ppt and 6ppt. The results obtained at 25°C were significantly lower (P<0.05) as compared to those obtained at 28 and 31°C (Table 1).

Effect of salinity on egg incubation period, hatching period and hatchability

The minimum egg incubation and hatching period of *C. gariepinus* at all treatment temperatures (25-31°C) was obtained at 3ppt (Table 2). There were no significant differences (P>0.05) in incubation and hatching period at 25°C but significant differences (P<0.05) were obtained at 28 and 31°C (Table 2). Salinity affected egg hatchability in that, at 25°C, egg hatchability was high in salty water than in freshwater, but at 28°C there was no significant difference (P>0.05) at all incubation salinities, while at 31°C, the highest incubation period was obtained in freshwater as compared to the salty water (Table 2).

Table 1: The effect of temperature on egg incubation period, hatching period and hatching period (mean±SE., n=9) of *Clarias gariepinus*

Salinity (ppt)	Temperature (°C)	Incubation period (h)	Hatching period (h)	Hatchability (%)
0.00	25	27.87±1.280^{a}	33.55±0.273^{a}	53.00±2.00^{b}
	28	24.42±0.500^{b}	28.05±0.464^{b}	76.00±1.00^{a}
	31	20.20±0.778^{c}	23.25±0.152^{c}	77.67±2.08^{a}
3.00	25	25.50±0.050^{a}	29.55±0.464^{a}	73.00±1.00^{a}
	28	19.50±0.060^{b}	22.67±0.115^{b}	78.00±2.65^{a}
	31	18.23±0.206^{c}	20.35±0.183^{c}	73.00±2.00^{a}
6.00	25	27.22±0.642^{a}	32.83±0.152^{a}	67.33±3.21^{b}
	28	24.12±0.206^{c}	26.82±0.206^{b}	77.00±1.00^{a}
	31	19.38±0.115^{b}	22.77±0.115^{c}	72.67±0.57^{a}

Means with the same superscript in a column are not significantly different (P>0.05)

Table 2: The effect of salinity on egg incubation and hatching period (mean±s.e., n=9) of *Clarias gariepinus*.

Temperatures (°C)	Salinity (ppt)	Incubation period (h)	Hatching period (h)	Hatchability (%)
25	0.00	27.87±1.280^{a}	33.55±0.273^{a}	53.00±2.00^{b}
	3.00	25.50±0.361^{a}	29.55±0.808^{a}	73.00±1.00^{a}
	6.00	27.22±0.642^{a}	32.82±0.966^{a}	67.33±3.21^{a}
28	0.00	24.42±0.050^{a}	28.05±0.464^{a}	76.00±1.00^{a}
	3.00	19.50±0.060^{b}	23.67±0.115^{b}	78.00±2.65^{a}
	6.00	24.12±0.778^{a}	26.82±0.183^{b}	77.00±1.00^{a}
31	0.00	20.20±0.778^{a}	23.25±0.152^{b}	77.67±2.08^{a}
	3.00	18.23±0.206^{c}	20.35±0.206^{c}	73.00±2.00^{b}
	6.00	19.38±0.115^{b}	22.77±0.115^{a}	72.67±0.57^{b}

Means with the same superscript in a column are not significantly different (P>0.05)

Interactive effect of temperature and salinity on incubation and hatching period and hatchability

The combination of temperature and salinity affected egg incubation period, hatching period and hatchability in that; the shortest incubation and hatching period were obtained at 31°C and 3ppt however this was not significantly lower (P>0.05) than those obtained at 28° C and 3ppt and those obtained at 31°C and 6ppt, while the highest incubation and hatching period were obtained at 0ppt and 25°C but these were not significantly higher (P>0.05) than those obtained at 6ppt and 25°C (Table 3). The highest hatchability was obtained at temperature-salinity combination of 28°C and 3ppt However this was not significantly higher (P>0.05) than those which were obtained at 31°C and 0 ppt, 28° C and 6ppt, 28°C and 0ppt, respectively and the least hatchability was obtained at 25°C and 0ppt (Table 3).

Table 3: The interactive effect of temperature and salinity on egg Incubation period, Hatching period and Hatchability (mean±SE., n=9) of *Clarias gariepinus*.

Temperatures (°C)	Salinity (ppt)	Incubation period (h)	Hatching period (h)	Hatchability (%)
25	0.00	27.87 ± 1.280^{a}	33.55 ± 0.273^{a}	53.00 ± 2.00^{c}
	3.00	25.50 ± 0.361^{b}	29.55 ± 0.208^{b}	73.00 ± 1.00^{b}
	6.00	27.22 ± 0.642^{a}	32.83 ± 0.966^{a}	67.33 ± 3.21^{b}
28	0.00	24.42 ± 0.050^{b}	28.05 ± 0.273^{b}	76.00 ± 1.00^{a}
	3.00	19.50 ± 0.060^{cd}	22.67 ± 0.208^{cd}	78.00 ± 2.65^{a}
	6.00	24.12 ± 0.778^{b}	26.82 ± 0.966^{b}	77.00 ± 1.00^{a}
31	0.00	20.20 ± 0.778^{c}	23.25 ± 0.152^{c}	77.67 ± 2.08^{a}
	3.00	18.23 ± 0.206^{d}	20.35 ± 0.206^{d}	73.00 ± 2.00^{b}
	6.00	19.38 ± 0.115^{c}	22.77 ± 0.115^{c}	72.67 ± 0.57^{b}

Means with the same superscript in a column are not significantly different (P>0.05)

Discussion

The results show that the incubation and hatching period decreased with increasing temperature at all the three incubation salinities (0-6ppt). Similar findings were reported by Nwosu and Hertzlohner (2000) and Haylor and Mollah (1995) when they incubated *Heterobranchus longifilis* (a sister catfish to *C. gariepinus*) and *C. gariepinus* eggs, respectively, at different temperatures. On the other hand, at all the three incubation temperatures from 25-31°C, increased salinity from 0-6ppt accelerated incubation and hatching period of *C. gariepinus*, however the incubation and hatching period was least at all the three incubation temperatures when eggs were incubated at 3ppt than those obtained at 0ppt and 6ppt. This agrees with Tomasz *et al*.(1997) who reported that salty water provides a suitable environment for egg hatching, and the results from the current experiment suggests that the suitable salinity for hatching of *C. gariepinus* eggs is 3ppt. Gbulubo and Erondu (1998) reported that eggs of the African catfish are hypo-osmotic to the fluid of the parent and are not capable of making physiological adjustments which can enhance their survival beyond 7ppt. Temperature affected egg hatchability in that at 0ppt, egg hatchability increased with increasing temperature. Similar results were reported by Haylor and Mollah (1995), who reported that *C. gariepinus* eggs can be successfully hatched at ambient water temperatures between 20 and 35°C, although at 30°C the hatching rate was significantly improved. Legendre and Teugels (1991) who obtained eggs from *H. longifilis* females reared at temperatures of 28 to 32°C in a lagoon environment (saline water) and recorded hatching even up to 35°C. Hogendoorn and Vismans (1980) and Hogendoorn *et al*. (1983) recommended that a temperature range of 27.5-32.5°C ensures optimal conditions for the incubation of eggs of *C. gariepinus*. Therefore the results suggests that in saline water, the best egg hatchability shifts (tends) towards the optimal temperature.

Salinity on the other hand affected egg hatchability in such a way that at 25°C, egg hatchability increases with increased salinity. These findings do not differ much from those reported by Borode and Akin-James (2005) who incubated the eggs of a hybrid of *C. gariepinus* (m) x *H. bidorsalis* (f) at 23-24°C and obtained the highest hatchability in salty water i.e. 6ppt than in freshwater though they did not indicate the exact figures.

Since in this current study the results recorded at 6ppt do not significantly differ from those recorded at 3ppt therefore they are in line with their results. The high hatchability observed at slightly higher salinities can be explained in two ways, first, the sodium chloride (common salt) acts as a therapeuutic agent to control bacteria and parasites in fish controlled culture and secondly, the sodium chloride maintains the required concentration level for fish culture in tank (Tomasz *et al*., 1997).

At 28°C, there were no significant differences in egg hatchability at the three incubation salinities (Table 2). Similar results were reported by Fasion-Bombat and

Basari (2003) who incubated eggs of *H. longifilis* at 27±0.5°C and reported the highest egg hatchability of 75% at 3ppt. On the other hand the results obtained in the current study are higher than those reported by Gbulubo and Eroddu (1998) who reported a hatchability of 65% at 0ppt, 56.5% at 3ppt and 21.1% at 6ppt when they incubated *C. gariepinus* eggs at 27.5°C, the difference could have been due to the fact that they used brackish water instead of sodium chloride as their test solution.

At 31°C, the findings show that egg hatchability was lower in salty water than in freshwater. These results are in agreement with those reported by Tomasz *et al*. (1997), who reported that the survival of *C. gariepinus* embryos decreased with increased salinity. They reported the survival of embryos to be 95.5% at 0ppt, 82.3% at 5ppt, and 0% at 10ppt, when they incubated *C. gariepinus* eggs at 30 ± 0.5°C. The difference between the hatchability in their study and the current study could have risen due to the slightly lower temperature they used in their study in addition to the wide range of salinity as compared to that used in the current study.

The least incubation and hatching period was obtained at temperature-salinity combination of 28°C and 3ppt and 31°C and 3ppt. Different results were reported by Nwosu and Hertzlohner (2000), who reported that the time from fertilization to hatching of *H. longifilis* eggs at 29°C ranged from 23 to 32h. When these results are compared with those obtained in the current study, it suggests that salinity accelerates hatching of *C.gariepinus* eggs.

The best temperature-salinity combination for egg hatchability was 28°C and 3ppt. Different results were reported by Gbulubo and Erodu (1998), who studied the effect of salinity on early stages of *C. gariepinus* eggs and reported the highest hatchability of 65% at 0ppt and 27±0.5°C, 56.5% at 3ppt, and 30% at 6ppt, at the same temperature. The lower percentage hatchability obtained as compared to the current study might have been due to the fact that they used blackish water instead of sodium chloride which was used in the current study. The results are also in contrast with those reported by Nwosu and Hertlzlohner (2000), who reported that at temperature range of 28-32°C, eggs of *H. longifilis* could not hatch because the temperatures were extreme, therefore they suffered from thermal shock. However similar results were reported by Legendre and Teugels (1991) who obtained eggs from *H. longifilis* females reared at a temperature of 28 to 32°C in a lagoon environment (saline water) and recorded hatching even up to 35°C. Nwosu and Hertlzlohner (2000), further reported that it was not clear whether salinity plays any role in temperature tolerance of the eggs but when they compared the different levels of temperature tolerance they recorded in their study and those recorded by Legendre and Teugels (1991), they suggested that salinity could have an impact. From the results of the current study, it is suggested that salinity modified temperature effects on *C. gariepinus* egg hatchability at 3 and 6ppt salinity.

Therefore this study has shown that both temperature and salinity and their combination had a significant effect on egg incubation and hatching period and egg hatchability of *C. gariepinus*. The temperature and salinity combination of 28°C and 3ppt results into better performance of egg hatching as evidenced by having the least incubation and hatching period and the highest hatchability, therefore it is recommended that *C. gariepinus* eggs should incubated at a temperature-salinity combination of 28°C and 3ppt.

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References

Aktas, M, 2004. Combined effect of temperature and salinity on egg hatching rates and incubation time of *Penaeus semisulcatus* (Decapoda: Penaeidae). Israel journal, 2: 250-257.

Borode, A.O. and Akin–James O. 2005. Effect of salinity level on embryonic development, hatchability and survival potential of reciprocal hybrid larvae of Clariid catfish (*Clarias gariepinus* x *Heterobranchus bidorsalis)*. Journal of Food, Agriculture & Environment, 3: 243-248.

Borode, A.O., Balogun, A.M. and Omoyeni, B.A. 2002. Effect of salinity on embryonic development, hatchability and growth of African catfish, *Clarias gariepinus*, eggs and larvae. Journal of Applied Aquaculture, 12: 89-93.

Britz, P. J. 1991. The utility of hornoplastic pituitary glands for spawning induction of the African catfish *(Clarias gariepnus)* in commercial aquaculture in Africa. Water South Africa*,* 17, 237-241.

De Graaf, G. & Janssen, H. 1996. Artificial reproduction and pond rearing of the African catfish *Clarias gariepinus* in sub Saharran Africa. Fisheries Technical Paper 362. Food and Agricultural Organisation of the United Nations, Rome, Italy.

Gbulubo, A.J and Erondu, E.S. 1998. Salinity influence on early stages of the African catfish. Aquaculture international*,* 6, 369-379

Haniffa, M.A.K., and Sridhar, S. 2002. Induced spawning of spotted murrel *Channa punctatus)* and catfish *Heteropneustes fossilis* using human chorionic gonadotropin and synthetic hormone (*Ovaprim)*. Vetinary Achievement, 72: 51 – 56.

Haylor, G.S. 1993. Controlled hatchery production of African catfish, *Clarias gariepinus* (Burchell): an overview. Aquaculture and Fisheries Management, 24, 245-252.

Haylor, G. S. and Mollah, M.F.A. 1995. Controlled hatchery production of African catfish, *Clarias*

gariepinus: the influence of temperature on early development. Aquatic Living Resource, 8: 431-438.

Hecht, T., and Appelbaum, S. 1988. Observations on intraspecific aggression and coeval sibling cannibalism by larval and juvenile *Clarias gariepinus* (Clariidae: Piscis) under controlled conditions. Journal of Zoology London 214: 21-44.

Herzig, A. and H. Winkler, 1986. The influence of temperature on the embryonic development of three cyprinid fishes, *Abramis brama, Chalcalburnus chalcoides mento* and *Vimba vimba*. Journal of Fish Biology, 28:171–181.

Hocutt, C.H., 1989. Seasonal and diel behaviour of radio-tagged *Clarias gariepinus* in Lake Ngezi, Zimbabwe (Pisces:Clariidae). Journal of Zoology London 219: 181-199.

Hogendoorn, H. and Visman, M.M. 1980. Controlled propagation of the African catfish *Clarias lazera* (C and V) 11, Artificial reproduction. Aquaculture, 21, 39–53.

Hogendoorn, H., Jansen, J.A.J., Koops, W.J., Machiels, M.A.M., van Ewijk, P.H. and van Hees, J.P. 1983. Growth and production of the african catfish, *Clarias lazera* (C&V). II. Effects of body weight, temperature and feeding level in intensive tank culture. Aquaculture, 00:71-109.

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SOME ASPECTS OF REPRODUCTIVE BIOLOGY OF *OREOCHROMIS ANDERSONII* (CASTELNAU, 1869), *OREOCHROMIS MACHROCHIR* (BOULENGER, 1912) AND *OREOCHROMIS NILOTICUS* (LINNAEUS, 1758).

‡ Kefi, A. S[1]., Chimba, N[1]., Kancheya, C[1]., Mumba, D. C[1] and Kubiriza, K, G[2].

[1]National Aquaculture Research and Development Centre, P. O. Box 22797, Kitwe, Zambia.
[2]Department of Zoology, Makerere University, P. O Box 7062, Kampala, Uganda.
‡ The author to whom correspondence should be adressed: askefi@yahoo.com

Abstract
The study on the reproductive biology of *Oreochromis macrochir*, *O. niloticus* and *O. andersonii* was carried out at National Aquaculture Research and Development Centre (NARDC), Kitwe, Zambia, for sixty nine days in hapas set in 250m^2 semi-concrete ponds. Eggs were collected from mouths of brood fish of the three species at intervals of 21 days and taken to the laboratory for counting and measurement of length on the microscope with standardized calibrated eyepiece. There were no significant (P> 0.05) differences in the number and weight of eggs of the three fish species. *O. macrochir* incubated the largest number of eggs with the lowest weight. However, the egg length of *O. macrochir* was greater (P< 0.05) than other fish species. A negative relationship between egg number and weight was observed in all the three species. A positive correlation was found to exist between the length of the fish's size and number of the eggs in *O. machrochir* and *O. andersonii* while the opposite was observed in *O. niloticus*. The brooding index for *O. niloticus* (5.037 ± 1.865%) was the lowest followed by *O. macrochir* (11.989 ± 3.593%) and *O. andersonii* (14.721 ± 5.130%) suggesting that *O. niloticus* spends the least energy in reproduction among the studied species. Since *O. niloticus* is restricted to research stations and to farms permitted by authorities, the mesh sizes of the screens put on culture facilities should be smaller than 1.0mm to avoid eggs being washed away.

Key words: *Oreochromis,* Reproduction, Brooding index, Energy

Introduction

In Zambia, Tilapias (*Oreochromis* species) are the major cultured fish species because they are readily acceptable by consumers throughout the country (Mudenda, 2004). However, low fecundity of these species means that large numbers of brood fish must be kept (Ambali and Little, 1996) at a huge cost, if reasonable numbers of fish seed for stocking in fish ponds are to be produced. Therefore, dealing with strains that would produce sufficient and quality fingerlings would assist in solving the problem of inadequate fish seed while keeping in check, costs of maintaining a large number of brooders for the emerging fish farmers.

Given that *Oreochromis* species reared are mouth brooders with low fecundity there is need to explore their specific reproductive biology as a way of generating a baseline data that can be used to manipulate their reproductive potential. In Zambia, the indigenous *Oreochromis andersonii*, *O. macrochir* and *Tilapia rendalli* are the most grown fish species at 67.4% (Mudenda, 2004). However, the exotic *O. niloticus* that was introduced in 1982 (Schwanck, 2004) is steadily gaining popularity among the farmers (Mudenda, 2004) as it is believed to do better than the indigenous tilapia species. For one to culture *O. niloticus* authority must be granted by the government although it has been reported to have escaped into Kafue River systems.
The poor productivity of *Oreochromis* species is attributed to difficulties in managing the asynchronously breeding fish and failure to harvest fish seed efficiently (Ambali and Little, 1996). This study was carried out to investigate whether the exotic *O. niloticus* considerably differs in its reproductive performance from those of the indigenous *O. andersonii* and *O. macrochir*. It was aimed at assessing the egg number, length and weights of *O. andersonii*, *O. macrochir* and *O. niloticus* in Zambia. The results would help understand the reproductive parameters .

Materials and methods

This study was conducted at NARDC, Kitwe, Zambia for a period of sixty nine (69) days (1st October to 8th December 2008) in semi-concrete ponds (250m^2) with concrete walls with earth at the bottom. Four hapas (8 x 3 x 0.9m^3) were set in each of the three ponds with planks of wood placed on the sides to prevent fish escaping below the netting materials of the hapas. The ponds were 1 m apart.

Ponds were prepared by applying hydrated lime followed by chicken manure at 0.1kg/m^2 and 0.2kg/m respectively. There after no manure or lime was applied till the termination of the experiment. Water was then let to flow into the ponds up to 50 cm mark and allowed plankton to get established.

After seven days, the ponds were filled with water up

to the 70cm mark of the hapas allowing a 20cm free board to avoid fish jumping out of the hapas. Three days later the hapas were randomly stocked with sexually mature *Oreochromis* species at 3 fish/m^2 in 3:1 (females: males) sex ratio with females averaging (99.544 ± 5.885, mean; SE) seined from the similar ponds located close to the experimental ponds. A distended, swollen abdomen with the production of ripe eggs by slight press of the abdomen towards the genital papilla signified maturity for females. Similarly only males that produced sperm from the genital papilla after a slight press were selected. During the growing period (150 days), the experimental fish were fed twice a day (10:00 and 15:00 hrs) at 5% body weight with a 32% protein pellet manufactured by NARDC. The quantity of feed was adjusted every 30 days after sampling. To avoid mixing of species, each pond was allocated a single species of the three *Oreochromis* species (O. *andersonii*, *O. macrochir* and *O. niloticus*).

Fish mortality and water temperature were checked and monitored daily except on Sundays. Where mortality was observed, replacement of similar size and same sex was made to maintain the stocking density and sex ratio.

Eggs were collected from mouth of brood fish at intervals of 21 days. They were immediately put in the clean beaker and taken to the laboratory for counting, weighing (on digital weighing scale) and length measurement using ocular scale on the microscope after blotting them on paper. After collection of the eggs the fish were anesthetized using crude clove spice before the live weight (g), standard, and total length (mm) and mouth size of the brood fish were taken according to Skelton (2001).

Statistical analysis

Data on the number of eggs, length and weight were checked for normality and homogeneity and were analysed using analysis of variance (ANOVA). Significant differences in the main effects, means were compared using Duncan's Multiple Range Test (DMRT). Regression and correlation analyses were also done to describe the strength of the linear relationship among reproductive characteristics of the fish. All statistical analyses were performed using SPSS 12.0 for Windows .

Results

Relationship between fish size and mouth size

There was a strong, positive, correlation between the fish weight and mouth size variables (r = 0.789, n = 46, $P< 0.05$) with larger fish associated with a large mouth. The same trend was observed in specific species (*O. macrochir*, r = 0.479, n = 15, $P> 0.05$; *O. andersonii*, r = 0.422, n = 14, $P< 0.05$; *O. niloticus*, r = 0.824, n = 7, $P< 0.05$).

A scatter plot of fish length and the mouth size showed a strong positive and siginificant correlation (r = 0.688, n = 46). ($R^2 = 0.731$, F = 119.73, $P< 0.05$) (Figure. 1).

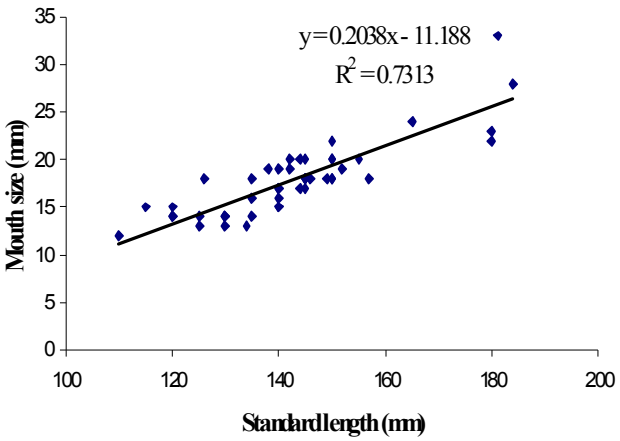

Figure 1: Relationship between standard length and mouth size of the fish.

Similar results were obtained in fish species *O. macrochir* (r = 0.584, n = 15, $P< 0.05$), *O. andersonii* (r = 0.594, n = 21, $P< 0.05$) and *O. niloticus* (r = 0.927, n = 7, $P< 0.05$).

Number of spawn in a mouth of fish

The mean number of eggs (mean ± SE) collected from mouth of fish was highest for *O. macrochir*, (789±209) followed by *O. andersonii* (639 ±130) and lastly for *O. niloticus* (605±138) (Figure 2). But the numbers were not significantly different across species ($P>0.05$).

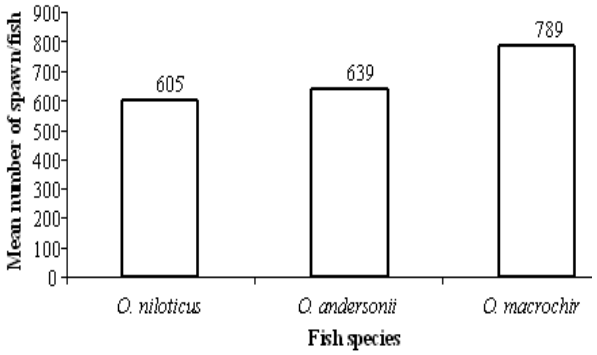

Figure 2: Mean number of eggs per female collected from mouths of broad fish.

Weight of eggs

The egg weight did not differ significantly ($P>0.05$) across the *Oreochromis* spp under study. However, the eggs of *O. andersonii* were the heaviest (22.622 ± 7.113mg), followed by *O. niloticus* (14.134 ± 5.988mg). *Oreochromis macrochir* had the lightest eggs (11.615 ± 2.974mg) (Figure 3).

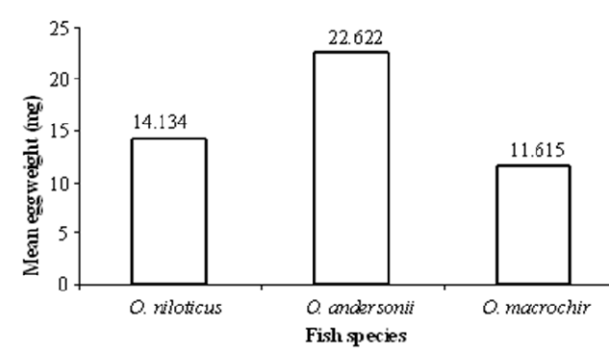

Figure 3: Mean egg weight of the *Oreochromis* spp at 21 days

Mean egg length

The egg length of *O. macrochir* (1.83 ± 0.044mm) and *O. niloticus* (1.78 ± 0.045mm) was significantly ($P<$ 0.05) higher than (1.601 ± 0.038mm) *O. andersonii* (Figure 4)

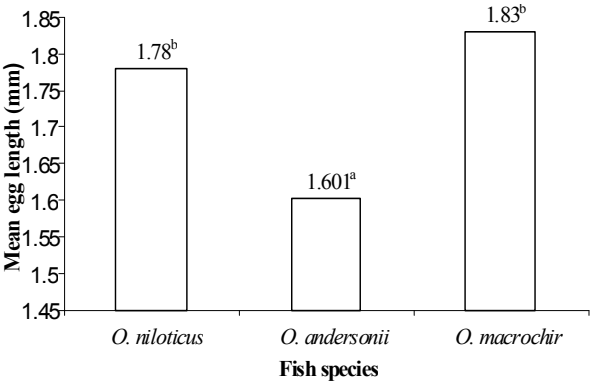

Figure 4: Mean egg length of *Oreochromis* species at 21 days interval.

Table 1: Minimum and maximum egg length, egg number per spawn and egg weight

Fish spp	Egg size (mm)		Egg number		Egg weight (mg)	
	Min	Max	Min	Max	Min	Max
Oreochromis macrochir	0.6	2.7	129	2, 440	5.95	50
Oreochromis niloticus	1.0	2.4	178	1, 355	7.257	50
Oreochromis andersonii	0.7	2.1	26	2, 300	7.106	50

Relationship between wet egg weight (mg) and number of eggs contained in the mouth of fish

A scatter plot of egg weight (g) in relation to the number of eggs contained in the mouth showed a negative correlation but with a lot of variation due to difficulties in the standardization of gelatinous egg masses (Kubiriza, 2007). Therefore, only 1.45% of the observed egg weight is explained by the number of eggs in the mouth (R^2 ± 0.0145, f).

The weight of eggs, however, was found to insignificantly determine individual egg number of the fish (R^2 = 0.0145, F = 0.572, $P>$ 0.05). Spearman Rank Order Correlation showed a weak, negative correlation between the number and weight of eggs for *O. macrochir* (r = -0.126, n = 14, $P>$ 0.05), *O. andersonii* (r = -0.097, n = 21, $P>$ 0.05) and *O. niloticus* (r = -0.160, n = 7, $P>$0.05), (Figure 5).

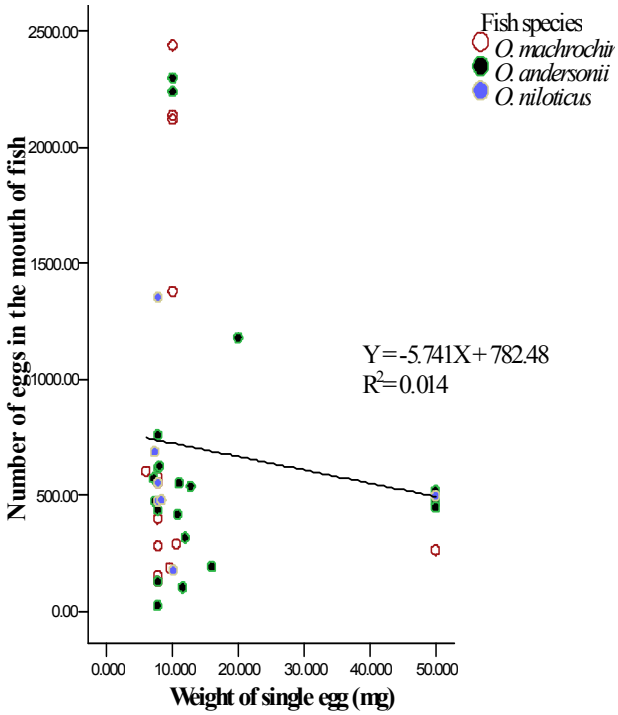

Figure 5: Relationship between number and weight of eggs

Relationships between fish mouth size, egg number and weight of eggs

There was a weak, positive, partial correlation between the mouth size of the fish and number of eggs in the mouth (r = 0.081, n = 32, $P>$ 0.05) and weight of eggs (r = 0.153, n = 32, $P>$0.05) with larger fish mouth size associated with higher numbers and heavier eggs. An inspection of the zero order correlation (r = 0.081) suggested controlling for fish weight and species had greater effect on the direction of the relationship. However, there was a weak, negative, partial correlation between fish weight and egg number (r = -0.124, n = 34, $P>$ 0.05) and weight (r = -0.175, n = 34, $P>$0.05).

In terms of individual fish species, both the indigenous (*O. macrochir*, r = 0.047, n = 15, $P>$0.05; *O. andersonii*, r = 0.09, n = 21, $P>$0.05) fish species showed a weak, positive correlation between fish mouth and number of eggs with a big mouth associated with a large number of eggs. However, *O. niloticus* indicated a weak, negative correlation between the mouth and the number of eggs(r = -0.2, n = 7, $P>$ 0.05).

Relationship between fish weight and number of eggs spawned

There were positive correlations between fish weight and egg numbers for *O. macrochir* (r = 0.084, n = 15, $P>$ 0.05) and significant correlation in *O. andersonii* (r

= 0.416, n = 21, $P< 0.05$) and *Oreochromis niloticus* (r = -0.346, n = 7, $P< 0.05$)

Table 2: Brooding index (mean ± SE) of *Oreochromis* spp

Fish species	Brooding index[1] (%)
Oreochromis niloticus	5.037 ± 1.865
reochromis macrochir	11.989 ± 3.593
Oreochromis andersonii	14.721 ± 5.130

[1] (Weight of eggs (g)/weight of fish (g) – weight of eggs (g)) *100

Discussion

The results of the current study show that the number of eggs incubated was not significantly different ($P>$ 0.05) although in absolute numbers those of *O. macrochir* (129 – 2, 440) were higher *O. andersonii* (26 – 2, 300) and *O. niloticus* (178 – 1, 355), The maximum number of eggs for *O. niloticus* was higher compared to what was observed by Peña – Mendoza *et al.* (2005). In their study *O. niloticus* had eggs that ranged between 243 and 847. The largest number of eggs counted in any mouth brooding cichlid was 4, 300 in *O. aurea* (Peña – Mendoza *et al.*, 2005). In general mouth brooding cichlids have a low fecundity as survival of the offspring becomes very important (Moyle and Cech, 2000). However, *O. macrochir* had the longest eggs compared to the other species although in terms of weight *O. andersonii* had the heaviest eggs, followed by *O. niloticus* with *O. macrochir* having the lightest eggs. Interestingly eggs in all the three species had the maximum weight of 50mg. The large number of eggs incubated by *O. macrochir* would be attributed to the eggs being light compared to those of the *O. niloticus* and *O. andersonii*. The smaller egg production requires less energy and thus allows production of more offspring (Huchette *et al.,* 2004). Smaller eggs for much studied *O. niloticus* were observed compared to those reported by Babiker & Ibrahim (1979) and Peña – Mendoza *et al.* (2005). The differences may be due to the variations in environmental conditions such as food. This is because the fertilized eggs rely on the nutritional components of the yolk as lipids, carbohydrates and proteins hing (Hardy, 1985).

Generally, there was a negative correlation between weight and number of the eggs contained in the mouth of fish with bigger spawn being associated with smaller numbers incubated in the mouth and the opposite was true. This implies that the volume of the mouth may be the dominant factor in the number of eggs that a fish can carry (Babiker and Ibrahim, 1979). This is consistent with the fact that the fish's mouth size was found to be positively correlated with the number of eggs. The current study is in conformity with studies done in other species. Baxter (1959) found an inverse relationship between fecundity and size of an egg on the population of herrings. Surveys of egg diameters of marine and freshwater species showed that frequency distribution was skewed towards smaller diameters (Wootton, 1979; Kamler, 1992; Winemiller and Rose, 1992; Wootton, 1998). Peters (1963), as quoted in Lowe-McConnell (1987) found the egg number was related reciprocally to egg weight, tilapia producing many small or few large eggs. Studies on *O. niloticus*, Peña – Mendoza *et al.* (2005) found oocyte number to increase with an increase in body length. This is because there is an evolutionary tendency in fish to minimize egg size. There is a trade – off between egg size and fecundity, given that the volume of abdominal cavity is limited. Fecundity can be maximized by minimizing the egg size (Wootton, 1998), as shown by *O. macrochir* in the current study. Bagenal (1957) studying on *Hippoglossoides* observed that egg numbers increase linearly with body weight. Similar results were observed in abalone by Babcock and Keesing (1999). Batch fecundity, which is the number of eggs produced per spawning, is a function of body size, because the batch fecundity will be related to the volume of the body cavity available to accommodate the ripe ovaries (Wootton, 1998).

Welcomme (1967) found that in the mouth brooding *Oreochromis leucostictus* the fertility increased with the square of the total length, the numbers of young being limited to the size of the mouth size which increases in linear relation to body length, so brooding efficiency decreases as the parent fish increases in length. Legendre and Trebaol (1996) studying on the brooding efficiency of *Sarotherodon melanotheron* found a positive linear relationship between the number of incubated eggs or fry and weight of the male brooders. In the current study, there was a negative correlation between fish weight and number of eggs spawned in *O. niloticus*. This shows that as this fish grows the brooding efficiency also declines. The indigenous fish species showed a positive relationship between fish weight and spawn numbers.

The early sexual maturity of *Oreochromis* species leads to overcrowding and stunting resulting in limited economic yields for fish farms (Baroiller and Toguyeni, 1996) since energy is directed to reproduction instead of somatic growth. A gonad that is small in comparison with total body size may represent a major investment of resources if the production and release of gametes is rapid (Wootton, 1998). Assuming the brooding index is a good indicator of the gonadosomatic index (GSI) then *O. niloticus* investment into brooding the progeny is the lowest compared to the *O. macrochir* and *O. andersonii* since a lower GSI indicates high reproductive efficiency. In fact Jegede (2008) recommended the use of the total egg weight in calculating the GSI if its main aim is determining the reproductive potential. The lower brooding index indicates that *O.*

niloticus directs the lowest energy towards reproduction allowing somatic growth even when it attains maturity.

Although there have been no comparative studies on the production traits such as growth of the species experimented in Zambia, there has been a general perception that *O. niloticus* is a better candidate in fish production as it grows faster compared to the other *Oreochromis* fish species. Juvenile *O. niloticus* has been found to be hardy when taken to the laboratory for experiments at NARDC. This would be attributed to the ability of the *O. niloticus* to maximize survival. Evolutionary greater larvae is derived from the bigger eggs and larger individuals minimize mortality (Kamler, 1992). This is because the optimal egg size is that which maximizes the number of offspring surviving to become reproductively active, so it is the size at which the product of fecundity and survival is maximum (Sibly and Calow, 1986; Wootton, 1998). Thus an increase in fecundity achieved by reduction in egg size is likely to be counterbalanced by a decrease in survival. However, these factors require further studies to establish whether the spawn number and size may have a direct or indirect influence on the growth and survival of the species in question. The results will help manipulate factors that would determine the survival and growth of the *Oreochromis* spp cultured in Zambia.

The experiment reveals that *O. macrochir* incubates slighter largest number of eggs of the three *Oreochromis* spp studied. However, its eggs were relatively smaller in terms of weight that would mean low survival. Since *O. niloticus* is restricted to research stations and to farms permitted by authorities, the mesh sizes of the screens put on culture facilities should be relatively smaller than 1.0mm in order to avoid eggs being washed into natural water bodies. However more studies are needed to ascertain the size of eggs (volume, diameter, surface area) of the three species and respective survival and growth of progeny.

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References

Ambali, A. J. D and Little, D. C. 1996. Studies on the effect of manipulating hapa size on broodstock conditioning of *Oreochromis niloticus* in fertilized earthen ponds, p. 223 – 228. *In* R. S. V Pullin, J. Lazard, M. Legendre, J. B. Amon Kothias and D. Pauly (eds). The Third International Symposium on Tilapia in Aquaculture. ICLARM Conference proceedings 41, 575 p.

Babcock, R and Keesing, J. 1999. Fertilization biology of abalone *Haliotis laevigata*: laboratory and field studies. Canadian Journal of fisheries and aquatic Science 56: 1668 - 1678.

Babiker, M. M and Ibrahim, H. H. 1979. Studies on the biology of reproduction in the cichlid *Tilapia nilotica:* Gonadal maturation and fecundity. Journal of fish Biology 14: 437 - 447.

Bagenal, T. B. 1957. The breeding and fecundity of the long rough dab, *Hippoglossoides platessoides* and associated cycle in condition. Journal of Marine Biology 36: 377 – 382.

Baroiller, J. F and Toguyeni, A. 1996. Comparative effects of natural androgen, 11β – Hydroxyandrostenedione, and a synthetic androgen, 17α – methyltestosterone, on the sex ratios of *Oreochromis niloticus,* p. 238 – 245. *In* R. S. V Pullin, J. Lazard, M. Legendre, J. B. Amon Kothias and D. Pauly (eds). The Third International Symposium on Tilapia in Aquaculture. ICLARM Conference proceedings 41, 575 p.

Baxter, J. G. 1959. Fecundity of winter-spring and summer-autumn herrings. Journal of Cons. Int. Explor. Mer 25: 73 – 80.

Hardy, R. 1985. Salmonid broodstock nutrition. In Iwamoto, R and Sower, S (eds), Salmonid. University of Washington, Seattle, 98 – 108.

Huchette, S. M. H., Soulard, J. P., Koh, C. S and Day, R. W. 2004. Maternal variability in the blacklip abalone *Haliotis rubra* leach (mollusca: Gastropoda): effect of egg size on fertilisation success. Aquaculture 231: 181 – 195.

Jegede, O. I. 2008. The fecundity and sizes in *Tilapia zillii* from Lekki Lagoon, Nigeria. Nigeria Journal of Fisheries 5: 38 - 48.

Kamler, E. 1992. Early life history of fish, Chapman and Hall, London.

Kubiriza, G. K. 2007. Effect of water temperature of survival, growth and reproductive performance of the medically important fresh water snail species of Lake Malawi, *Bulinus nyassanus* (smith, 1877) (Mollusca: Gastropoda). MSc. thesis, University of Malawi, p114.

Legendre, M and Trebaol, L. 1996. Mouthbrooding efficiency and spawning frequency of *Sarotherodon melanotheron* (Rüppel, 1852) in culture environments (Ebrié Lagoon, Côte d' Ivoire), p. 239 – 348. *In* R. S. V Pullin, J. Lazard, M. Legendre, J. B. Amon Kothias and D. Pauly (eds). The Third International Symposium on Tilapia in Aquaculture. ICLARM Conference proceedings 41, 575p.

Moyle, B. P and Cech Jr, J. J. 2000. Fishes: An introduction to ichthyology. Prentice Hall, New Jersey, U. S. A.

Mudenda, C. G. 2004. Economic Perspective of Aquaculture Development Strategy of Zambia. FAO/ ZAM/TCP 3006.

Peña – Mendoza, B., Gomez – Marquez, J. L., Salgado – Ugarte, I. H and Ramirez – Noguera, D. 2005. Reproductive biology of *Oreochromis niloticus*

(Perciformes : Cichlidae) at Emiliano Zapata dam, Morelos, Mexico 53: 515 - 522.

Schwanck, E. J. 2004. The introduced *Oreochromis niloticus* is spreading on Kafue floodplain, Zambia. Hydrobiologia 315: 143 – 147.

Sibly, R. M and Calow, P. 1986. Physiological ecology of animals, Blackwell, Oxford.

Skelton, P. 2001. A Complete Guide to the Freshwater Fishes of Southern Africa, Struik Publishers Cape town, RSA. 395 p

Welcomme, R. L. 1967. The relationship between fecundity and fertility in the mouthbrooding cichlid fish *Tilapia leucosticte*. Journal of Zoology, London 151: 453 – 468.

Winemiller, K. O and Rose, K. A. 1992. Patterns of life history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49: 2196 – 2218

Wootton, R. J. 1979. Energy costs of egg production and environmental determinants of fecundity in teleosts fishes. Symposium of Zoological Society of London 44: 133 - 159.

Wootton, R. J. 1998. Ecology of Teleost Fishes (2nd Ed), Kluwer Academic Publishers, Aberystwyth.

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