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Table of Contents: Volume 7 Number 11 December 2015

ARTICLES

Research Articles

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Full Length Research Paper

Application of geographic information system for inland fisheries management: A case study of Stratum VII (Yeji Sector), Volta Lake, Ghana

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A geographic information system (GIS)-modeling of fish production in the Stratum VII of the Volta Lake was undertaken with the objective of investigating temporal changes and modeling fish production into the future. Parameters used included number of canoes, number of fishers, and water level. Stratum VII of the Volta Lake is currently one of the areas with the highest fishing activities, the largest fish market at Yeji and relatively a research center. Nevertheless, the lake has faced many setbacks due to poor management and monitoring. In order to combat these challenges, this study was conducted to investigate the temporal changes and forecasting production of Stratum VII of the Volta Lake using Geographic Information System. Long term field data from 1970 to 1998 on fisheries were acquired and analyzed for modeling fish production from 1970 to 2060, using ArcGIS management tools and model builder. A hind cast was first performed to validate the model. The model, "CPUE model" predicted a depletion of the fish of Stratum VII by 2055 with a maximum of 22,779 tonnes at a fishing effort of 9,826 canoes and a CPUE of 10.76 kg/canoe/day in the year 2005. Long and short term data were also compared in the Stratum VII. The R^2 values of the correlation of the number of fishermen, number of canoes and the water level over the years are high (89.9%, 78.21%) and moderate (50.71%). These correlations showed a continuous increase in the fishing effort and decrease in the water level; trends that impact negatively on the fish production over the years. This study has established appropriate mechanism for incorporating field data into a GIS database to support fishery management in the Volta Lake.

Key words: Geographic information system (GIS) modeling, CPUE model, temporal changes, fish production, fishing effort.

INTRODUCTION

The management of inland fisheries in Ghana has gone through several challenges, such as poor monitoring, control and surveillance, and limited funds. These challenges have contributed to its poor management over

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the years and resulted in low decline of fishery stocks. Fishery surveys carried out over the years in Ghana have lacked an integrated and comprehensive system of data archiving, analyses, and policy formulation in a science-based manner.

In Volta Lake, after the construction of a dam across the lake, fish catches showed an initial steady rise from 3,000 tonnes in 1964 to a maximum of 62,000 tonnes in 1969 and then followed by a decline and stabilization at around 40,000 tonnes (IDAF Report, 1991). Not only the Volta Lake is used to generate electricity and transport goods and people; it is also a source of other activities, such as fishery resources, mangroves, medium for aquaculture, agriculture, forestry, livestock, wildlife, and mining for limestone (IDAF Report, 1991).

Fisheries management and planning have many spatial components (e.g. movements and migrations of resources, definition of fishing grounds, transportation networks, markets), and many serious issues like habitat loss and environmental degradation. This has become issues of great complexity for fisheries biologists, aquatic resource managers and decision makers to address, especially in developing countries. Conflicts generated by the multiple users over the resources could be minimized if adequate consideration is given to the geo-spatial (locational) component and also by the inclusion of the local knowledge of fishermen to improve management policies (Kyem, 2004). The incorporation of information and communication technologies, particularly geographic information systems (GIS) (Kyem, 2004), is one way to promote a better integration of data and to support spatial planning.

For some time now, fisheries policy framework in Ghana, with regards to the Volta Lake has aimed at increased fish production for domestic consumption and export, increased income and employment opportunities, and institutional strengthening; all in a manner consistent with the long term sustainability of the fisheries resource and sound environmental practices (MOFA, 2003). The development and implementation of management policies to address these problems have, in most cases, not been effective, because of a failure to use all available sources of information and knowledge. The myriad of information available from diverse sources requires application of GIS as a tool to integrate all data in inland fisheries of the Volta Lake, especially in Stratum VII where most of the harvest was recorded (Vanderpuye, 1984).

The lack of consistent data on the Lake has made estimation of stocks difficult and unreliable, hence failure for effective management. MOFA (2003) reported that past governments have failed to take full advantage of successful resource management paradigms for effective management of the resources of the lake.

Stratum VII of the Volta Lake is currently one of the areas with the highest fishing activity on Volta Lake and boasts of the largest fish market centre at Yeji.

Furthermore, many studies have been carried out in the area, allowing the existence of some data for GIS analyses. Also, Yeji serves as a major ferry crossing point between Northern and Southern Ghana. In 1996, there were 288 fishing villages located in the area (Stratum VII) with 8,068 canoes and a total of about 20,228 fishermen (De Graaf and Ofori-Danson, 1997).

The goal of this study was to use GIS, as a platform to investigate the temporal trend in the fisheries of Stratum VII of the Volta Lake and to forecast fish production up to 2060.

MATERIALS AND METHODS

Stratum VII (YEJI SECTOR), Volta Lake, Ghana

Study area

The study area is known as Stratum VII of Volta Lake, in Ghana, and lies between longitudes 0°10' to 1° 05'W and latitude 8° 8' to 8° 20'N and extends for about 60 km south and 50 km north of Yeji (Figure 1). The surface area of Stratum VII was estimated at 890,780 hectares (Ofori-Danson, 1999).

Lake level fluctuations and monthly commercial fish catches were recorded in the Yeji (Stratum VII) part of the lake from July 1989 to December 1991. Fish catching were high when the lake water levels were low and vice versa. The general trend of monthly fish catches for the Yeji part of the lake was highly influenced by high tilapia catches in the area. When lake levels were high, tilapia catches were low, and vice versa (Abban and Dankwa, 2006). Thirty-six years after the formation of the lake, the commercial fish landings were dominated by tilapiine species not only in the lacustrine south, but throughout the lake. Also, those species previously considered to be mainly limited to riverine conditions (*Hydrocynus* species, *Labeo* species, *Mormyrids, Schilbeids, Odaxothrissa mento, Brycinus burse, Alestes baremose, Alestes dentex*, and *Citharinus* species) have returned to what was originally described as lacustrine parts of the lake. Stabilization of suitable conditions has probably enabled the species to exist in areas where they previously were not commonly found (Abban and Dankwa, 2006).

The Stratum VII from inception was divided into substrata or into banks for research purposes. The subdivision of the study area into two banks (Figure 1) was also adopted by the various frame surveys (Bazigos, 1970; Coppola and Agadzi, 1976; Braimah, 2000).

Database system

Long term data (1970 to 1996) pertaining to the work were obtained from appropriate institutions, such as the Water Research Institute (WRI), the Fisheries Commission, the Volta River Authority (VRA), the Hydrological Survey Department (HSD), Volta Basin River Project and FAO (1997). Some were obtained from individual researchers. Data from previous works were put in a spatial georeference database that could be updated any time new data is added. The data were mainly obtained from Volta Lake Research Project (1971, 1977), Vanderpuye (1984), Integrated Development of Artisanal Fisheries (IDAF) reports (1991, 1992, 1993, 1994, 1995, 1996, 1997), Agyenim-Boateng (1989), Braimah (1995, 2000), De Graaf and Ofori-Danson (1997), MOFA (2003), and Abban and Dankwa (2006)

A fisheries spatial database (Table 1) was developed and

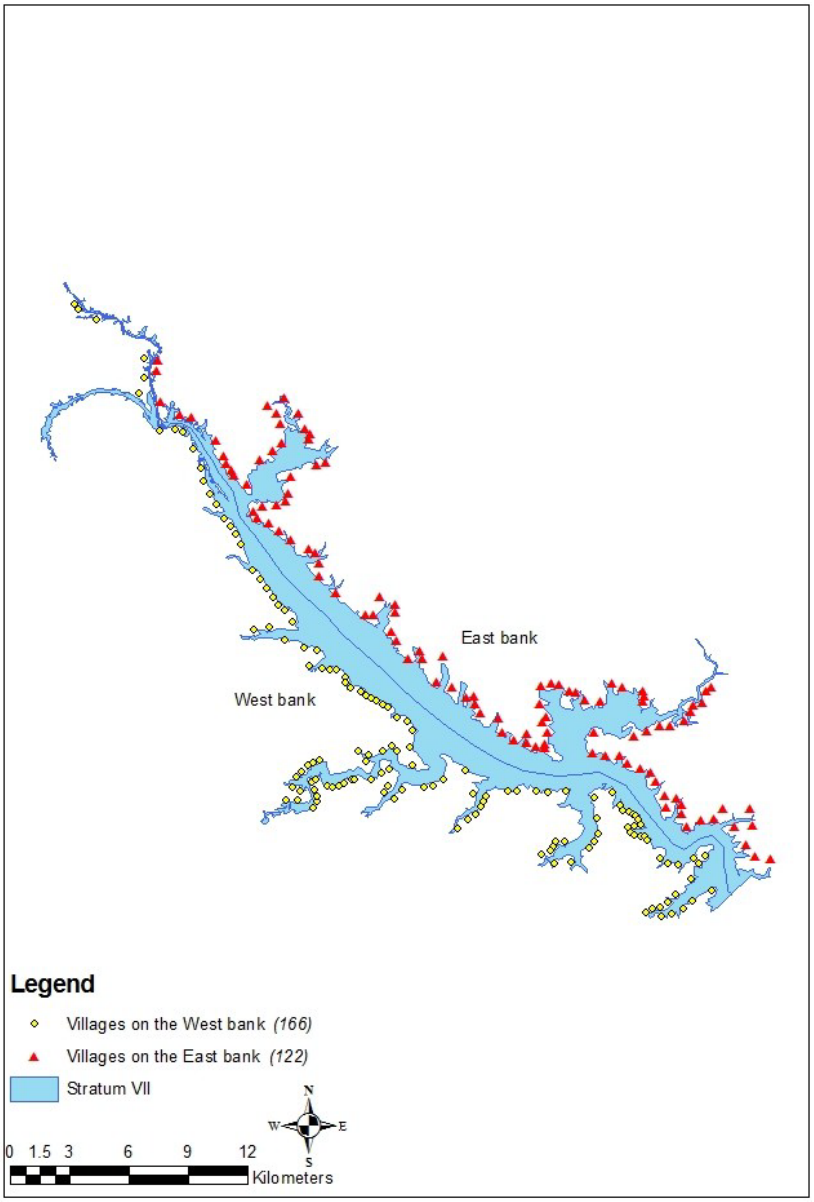

Figure 1. East and West banks of Stratum VII and their fishing villages.

information was allocated into local, regional, and national components so as to adopt for the development of the environmental geo-spatial database. The availability of GPS coordinates the landing sites (villages) and shapefile of Stratum VII enabled a gridded geographic analysis system that could be used for efficient management of the frame survey results. ArcGIS 9.3 software was used to perform the various tasks (visualization of data and building the models).

Comparative study of the fisheries of Stratum VII

The Stratum VII of the Volta Lake was digitized into two banks: East and West banks as by the various frame surveys (Bazigos, 1970; Coppola and Agadzi, 1976; Braimah, 2000). The data stored in attributes tables, were joined with locations on the Stratum VII and fisheries descriptive data (number of fishermen, CPUE, and total catch) were mapped using Arc Map.

Process of filling data gaps in historical frame survey

Data obtained from various institutions and literature was heterogeneous and full of gaps. These gaps needed to be completed so that enough long term data could be obtained for the modeling. Using 1996 as the baseline year, the parameters used for developing the model (that is, number of canoes, number of fishermen, CPUE, and water level) were calculated from the developed expression:

$$P_n = P_{1996} + R_p\,(n - 1996) \quad (1)$$

Table 1. Datasets included in the GIS database.

Data theme	Dataset	Information
Fisheries data	Frame survey	Number of fishermen number of canoes
	Catch assessment	CPUE Effort Total catch
Environmental data	Hydroghaphy	Water level
	Villages	Number of villages Geographical location

where P_n is the parameter at year n: F_n, C_n with F being the number of fishermen and C the number of canoes; P_{1996} is the value of the parameter in 1996 (F_{1996} = 20228, C_{1996} = 8068, W_{1996} = 76.5 m, $CPUE_{1996}$ = 12.70 kg/canoe/day); R_p is the rate of change in the parameter over the years. The CPUE values obtained through these calculations were used to validate the model. While filling in the gaps, the averages of available data were taken into consideration. The following relation was also developed to estimate the total catch in stratum VII using data from the market:

Total catch for particular year = (Mean of available total catches divided by mean of fish supplies at the market) X Yeji market fish supply for a particular year) (2)

The model was built with the model builder incorporated in ArcGIS 9.3 and developed with linear regression analyses using field data. The inputs were layers containing needed attributes: value of the needed parameters, fraction of fishing canoes, number of fishing days, and the shapefile of Stratum VII. The model was based on predicting the total catch based on the CPUE. Different multilinear regression analyses were performed to see the impact of the number of villages, the number of fishermen, the number of canoes, or water level on the CPUE. The best was obtained among the number of fishermen, the number of canoes and the water level and was used in the model. The relation was then used to calculate the CPUE in the model, therefore the name “CPUE model”. The following equations, initially developed by De Graaf and Ofori-Danson (1997) were modified and used to develop the “CPUE model”:

Canoe days in a year = [0.12 × (days in the year - 48) + 0.88 × (days in the year)] × (active number of canoes). (3)

Active number of canoes = (Number of canoes) x (fraction of the canoes that went fishing) (4)

Annual total catch (kg) = (Canoes days) × mean annual CPUE (kg/canoe/day) (5)

The models’ parameters were: the Stratum VII shapefile, the estimated fish catch, and the difference X (between the year which data is to be estimated and the baseline year). The parameters must be specified when running the models. The values (number of villages, number of fishermen, number of canoes, and water level) of the year 1996 were used as a baseline in the “CPUE model”. The “CPUE model” estimated the total fish production based on the CPUE obtained.

CPUE= 5.84 - (0.0003 x number of fishermen) + (0.169 x water level) (6)

The following assumptions were made due to lack of data in developing the models: Limno-chemical factors were not affecting the fishery of Stratum VII; Rates of changes (R_F, R_C and R_w) remain constant for all years; Stratum VII was considered as a closed system, hence no movement of fish in and out of Stratum VII was considered; Fraction of the canoes engaged in fishing was constant over the years; Relations among the parameters were all linear.

The following Statistical analyses were performed: ArcGIS 9.3 spatial analyst and data management tools were used to develop the model; A linear regression analyses was performed: Pearson correlation coefficient "r", p-value, and R^2.

RESULTS

Gaps in data were filled and Table 2 was obtained.

Comparative study of the fisheries of the east and west banks of Stratum VII

Stratum VII was partitioned into two banks: East and West banks, based on the frame surveys of 1970, 1975, and 1998 (Bazigos, 1970; Coppola and Agadzi, 1976; Braimah, 2000); and the socio-economic surveys of 1989 (Agyenim-Boateng, 1989) and 1991 (Maembe, 1992). The shapefiles of the banks (West and East) were given, respectively 1 and 2 as field Id. Any attribute that was related to a particular bank was given the same field Id and then linked to the digitized map. The process of comparing fisheries data over the years (1970 to 1998) involved the creation of attribute tables that were joined to the banks shapefiles and then mapped (Figures 2 and 3).

Forecasting fish production into the next 50 years

The rates of change in the parameters were obtained using the existing data. There is no significant relationship between the number of fishermen and the year r = 0.95, p > 0.05. The p-value = 0.052. There is a significant relationship between the number of canoes and the year r = 0.88, p < 0.05. The p-value = 0.019.

Table 2. Estimated data (in bold) from existing data.

Year	Number of fishermen	Number of canoes	Water level (m)	CPUE (kg/canoe/day)	Yeji Market (tonnes)	Total catch (tonnes)
1970	1,513	1,738	82.8	19.40	20,007	63,741
1975	4,562	1,913	79	18.13	17,101	54,484
1989	14,353	3,952	80.3	14.56	8,965	28,564
1991	18,157	5,617	80.3	14.05	9,041	27,300
1992	18,300	6,500	80.8	13.79	9,162	29,190
1993	18,399	7,479	77.6	13.54	8,262	26,323
1994	19,009	7,675	75.6	13.28	9,341	29,761
1995	19,618	7,870	76.4	13.03	6,426	20,473
1996	20,228	8,068	76.5	12.77	6,158	22,422
1997	20,838	6,719	74.9	12.52	6,232	19,855
1998	17,278	5,369	73.9	12.26	7,222	23,010

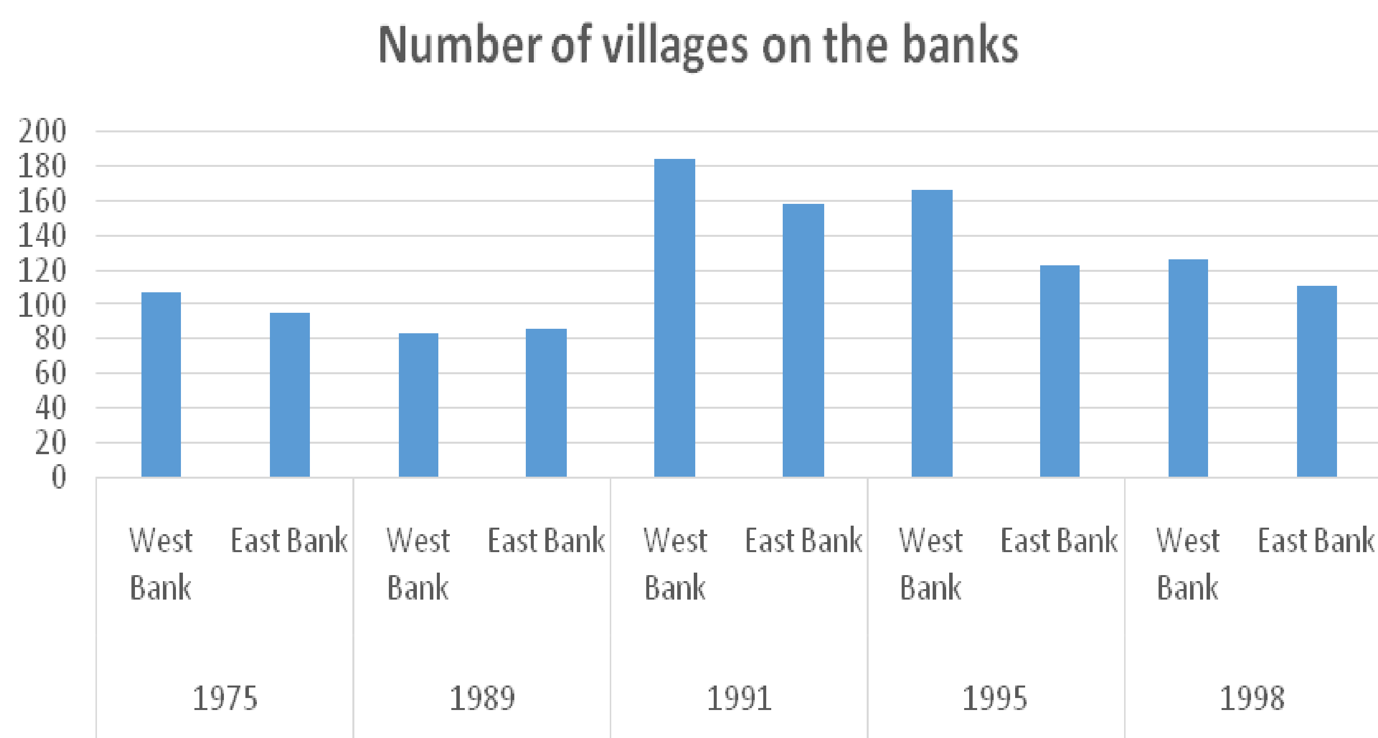

Figure 2. Variation in the number of fishing villages on the East and West banks of Stratum VII over the years.

There is a significant relationship between the number of canoes and the year r = 0.88, $p < 0.05$. The p-value = 0.019.

R_F represented the *rate* of change in number of fishermen and was 609.76 fishermen/year. R_C represented the rate of change in number of canoes and was 195.28 canoes/year. R_W represented the rate of change in water level and was -0.196 m/year. R_{CPUE} represented the rate of change in CPUE -0.255 kg/canoe/day (MOFA, 2003). The R^2 value in the graphs (Figures 4, 5, and 6) are respectively 89.9, 78.21, and 50.71%. The "CPUE model" is as shown in Figure 7.

Table 3 and Figure 8 were obtained when the "CPUE model" was run and the results plotted against the years, for the years 1970 to 2060.

The estimated fish production in 1970 was around 12,000 tonnes. In about 60 years (2055) from the baseline (1996) the CPUE value equaled 0. The maximum yield was 22,779 tonnes in the Stratum VII which was attained in 2005 at a fishing effort of 9,826

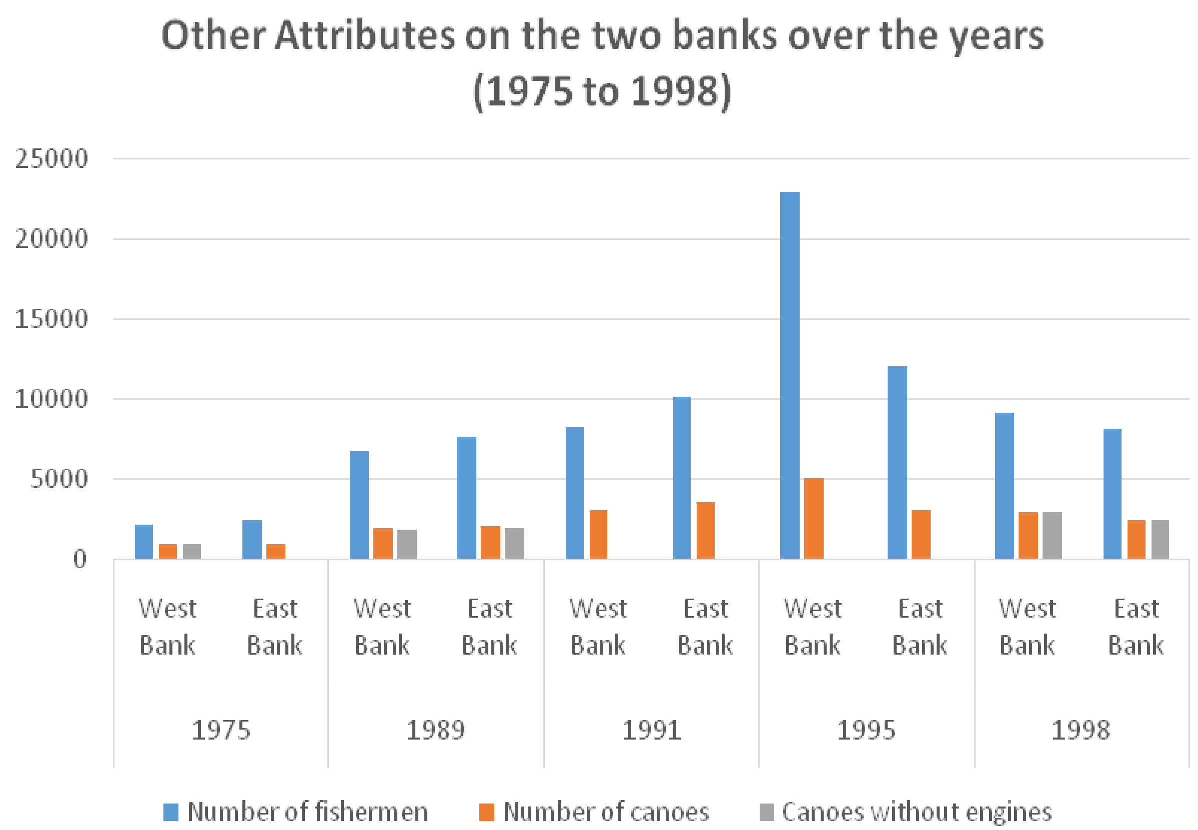

Figure 3. Comparison of in the number of fishermen, canoes and canoes without engines on the East and West banks of Stratum VII over the years.

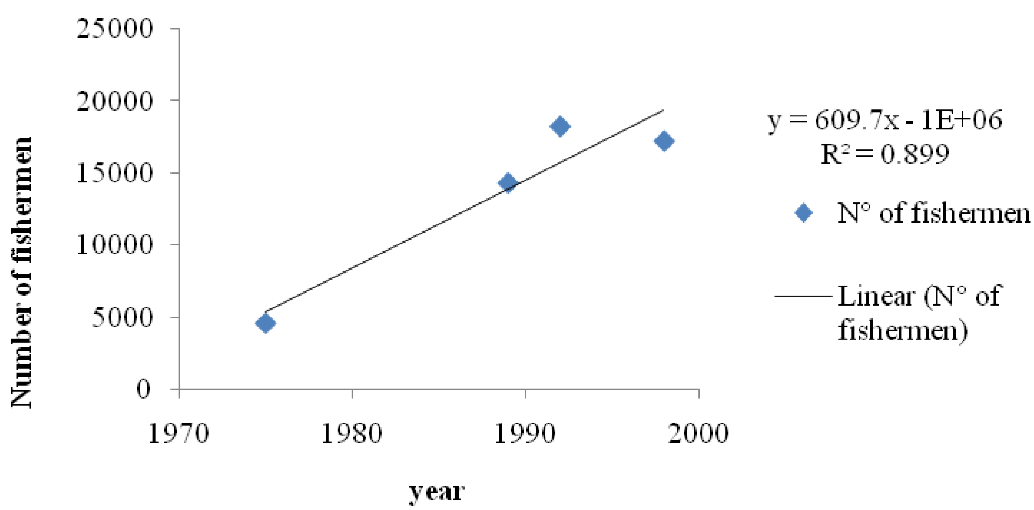

Figure 4. Change in number of fishermen from 1975 to 1998.

canoes and a CPUE of 10.76 kg/canoe/day. The surface area of Stratum VII was 890,780 hectares (Ofori-Danson, 1999).

The Pearson product moment correlation coefficient "r" that reflects the extent of a linear relationship between the two data sets was calculated for the data (Table 4).

The correlation coefficients were high or relatively high in almost all the cases except for the estimated total

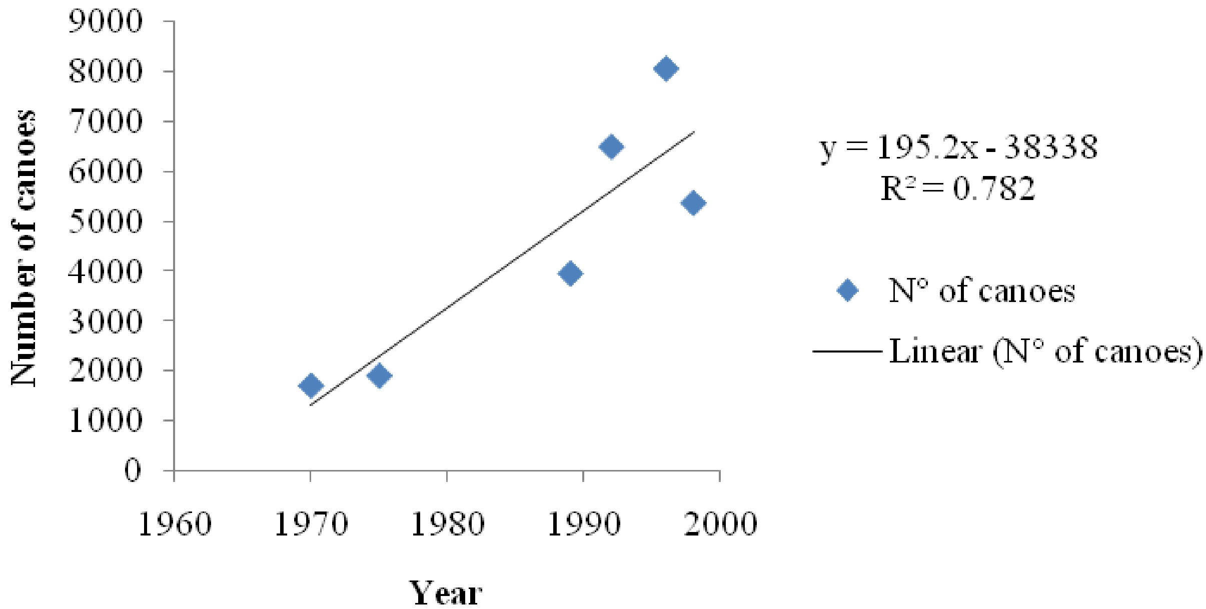

Figure 5. Change in number of canoes from 1970 to 1998.

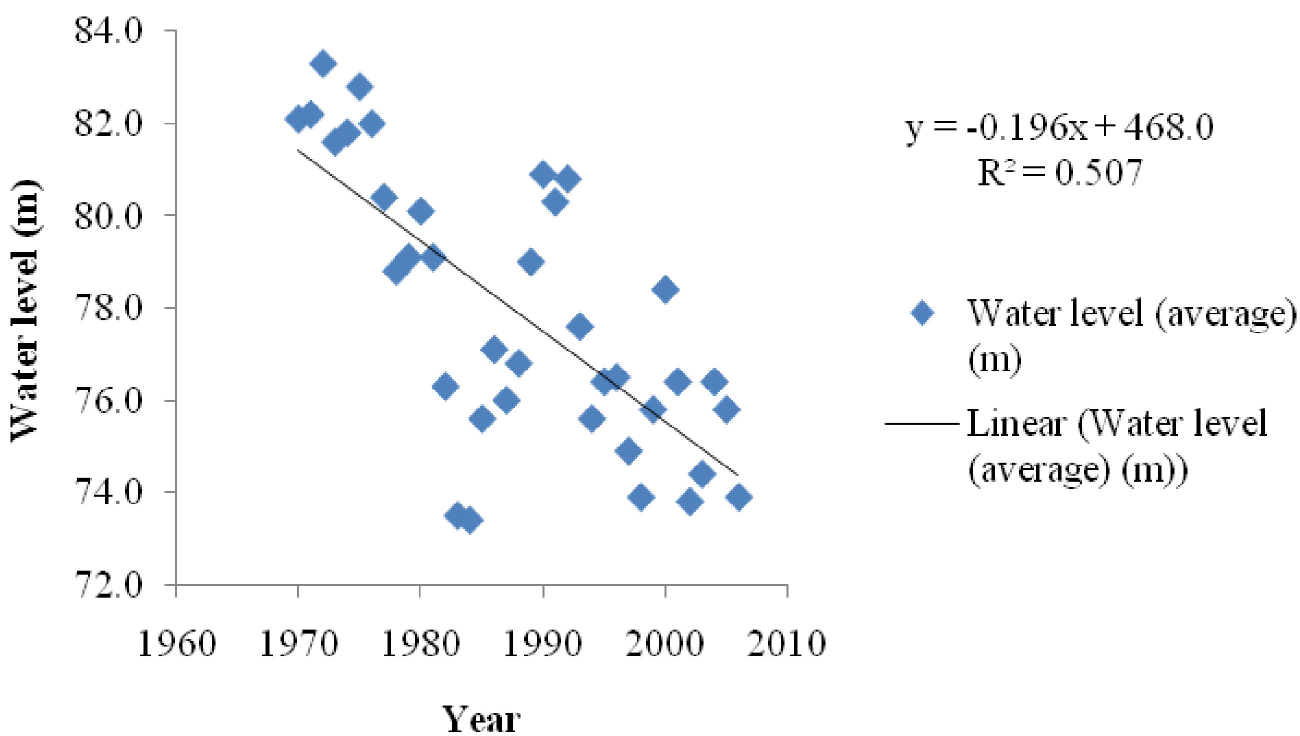

Figure 6. Change in water level (m) from 1970 to 2006.

Catch from the field and the one obtained through the “CPUE model”, where r = -0.99.

The number of fishermen generated by the “CPUE model” was in average higher than the field data and keeps increasing with the Pearson correlation coefficient r = 0.95. The number of canoes generated by the model was very high compare to the number of canoes on the ground and it kept increasing over the years. The

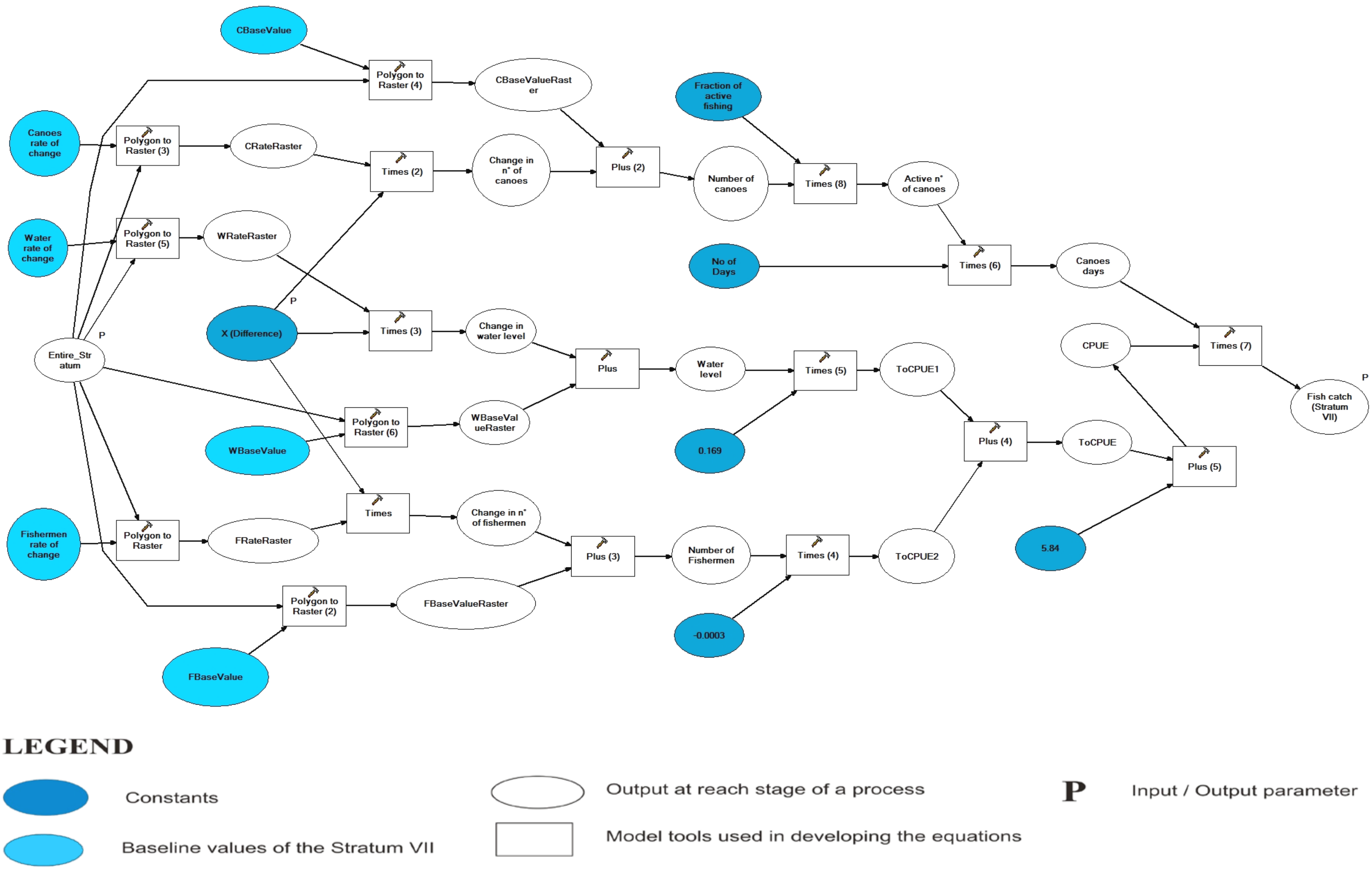

Figure 7. Developed “CPUE model” to predict the total catch in Stratum VII of the Volta Lake.

Table 3. Data obtained when the "CPUE model" was run over the years (1970 to 2055).

Year	Number of fishermen	Number of canoes	Water level (m)	CPUE (kg/canoe/day)	Total catch (tonnes)
1970	4,374	2,991	81.6	18.32	11,808
1975	7,423	3,967	80.6	17.24	14,739
1989	15,960	6,701	77.9	14.21	20,528
1991	17,179	7,091	77.5	13.78	21,064
1992	17,789	7,287	77.3	13.56	21,305
1993	18,399	7,482	77.1	13.35	21,527
1994	19,009	7,677	76.9	13.13	21,732
1995	19,618	7,873	76.7	12.92	21,918
1996	20,228	8,068	76.5	12.70	22,086
1997	20,838	8,263	76.3	12.48	22,235
1998	21,448	8,459	76.1	12.27	22,367
2000	22,667	8,849	75.7	11.84	22,576
2005	25,545	9,826	74.7	10.76	22,779
2006	26,326	10,021	74.5	10.54	22,765
2007	26,935	10,216	74.3	10.32	22,733
2008	27,545	10,411	74.1	10.10	22,672
2012	29,984	11,193	73.4	9.24	22,299
2015	31,813	11,778	72.8	8.59	21,820
2020	34,862	12,755	71.8	7.51	20,660
2050	53,155	18,613	65.9	1.03	4,146
2054	55,594	19,394	65.1	0.17	707

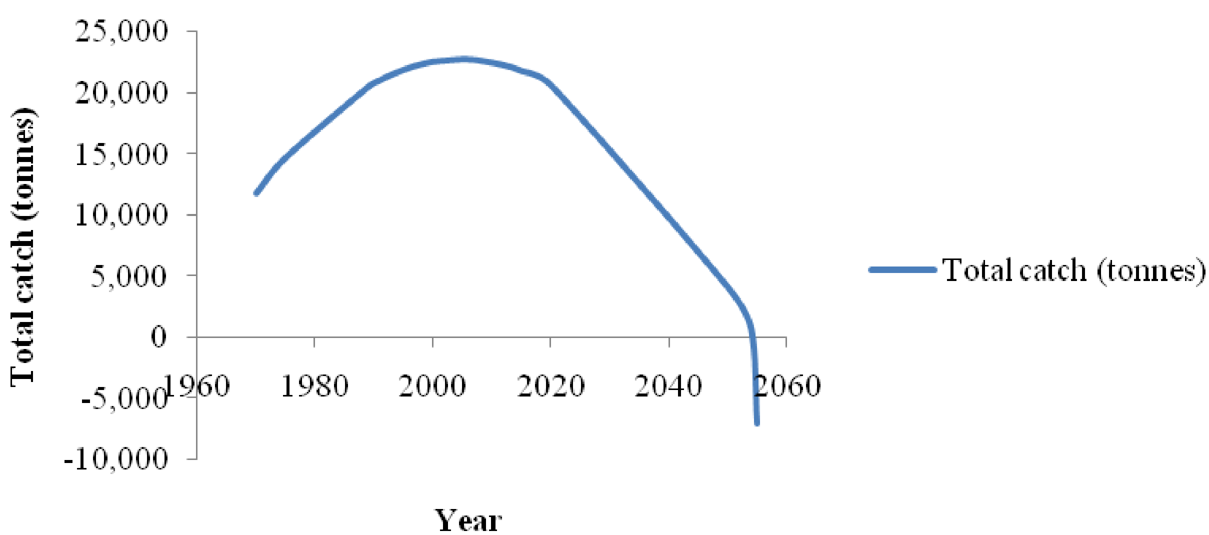

Figure 8. Model results of total catches from 1970 to 2060 in Stratum VII.

Pearson correlation coefficient r was 0.9.

DISCUSSION

The maximum yield obtained from the "CPUE model" and reached in the year 2005 with 22,779 tonnes at fishing effort of 9,826 canoes and a CPUE of 10.76 kg/canoe/day, implied that currently the fisheries resources are under serious threats. The R^2 values of the correlation of the number of fishermen, number of canoes, and the water level over the years are high and hence well fitted (89.9 and 78.21%) and moderate (50.71%). These correlations showed a continuous increase in the fishing effort and

Table 4. Pearson product moment correlation coefficients for the data with significant levels ($P < 0.05$).

Variable 1	Variable 2	Pearson correlation coefficient "r"
Number of fishermen (field data)	Number of fishermen (model)	0.95
Number of canoes (field data)	Number of canoes (model)	0.90
CPUE (Field data)	CPUE (CPUE model)	1.00
Water level (Field data)	Water level (model)	0.73
Total catch (Field data)	Total catches (CPUE model)	-0.99

decrease in the water level; trends that impact negatively on the fish production over the years. In 1998, the number of actively fishing canoes was 17274, hence, a loss of GH¢ 1.45 millions knowing that at the break-even point, where revenue is equal to cost and rent is zero, the effort was 17062 (MOFA, 2003). It showed that as at 1998, the fishing effort was already above the break-even point. The model predicted that by the year 2050 the number of canoes in the Stratum VII alone would be around 19,000 and therefore aggravating the state of the fishery resources and indirectly the economy in the whole Volta Lake. Due to the logistic nature of the model, the fisheries resources would be totally depleted by the year 2060.

This study confirmed the observed increasing trends in effort and the dramatic decrease in CPUE and total catch observed by Abban and Dankwa (2006). The decline in the number of canoes motorized canoes over the years might be due to a deficient management over the years as well as low revenue of fishers over the year (Fabio et al., 2003); hence, unable to maintain or afford engines. The absence of canoe with engines on the West bank in 1975 could be attributed to the nature of the banks. The East bank probably has less tree stumps (Gordon, 1999) in the lake compare to the West bank; hence, ease the deployment of outboard motors.

This work depicts three major problems that face inland fisheries in Ghana: poor or total absence of data keeping, lack of adequate budgetary allocations to the fisheries sub-sector and poor or total absence of monitoring over the years.

This study was limited by the assumptions made to develop the model. It was due to the limno-chemical factors that were absent and therefore not used, the absence of spatial and consistent data, the heterogeneity of the data, the socio-economic dynamics, the impacts of climate change (MOFA, 2003), and the management measures taken on the fisheries.

Conclusion

The management of inland fisheries in Ghana has gone through several challenges such as poor monitoring, control and surveillance, inadequate staffing and limited funds. These challenges have contributed to its poor management over the years and resulted in low decline of fish stocks. Fishery surveys carried out over the years in Ghana have lacked an integrated and comprehensive system of data archiving, analyses and policy formulation in a science-based manner. This study was designed to use GIS, as a platform to investigate the fisheries of Stratum VII of the Volta Lake and to forecast fish production for 2060.

It has developed a model that gave a forecast of the fish production in this region. Canoes fish production was modeled over 50 years using the model builder in ArcGIS 9.3. The model (CPUE model) was developed with long term data obtained from the field. The “CPUE model” based on using CPUE data, showed a maximum yield of 22,779 tonnes at a fishing effort of 9,826 canoes and a CPUE of 10.76 kg/canoe/day in the year 2005. The model predicted a total depletion of the fishery of Stratum VII by the year 2055. It confirmed the study by De Graaf and Ofori-Danson (1997) which has shown that the total fish production (40,000 tonnes) of the Volta Lake has been underestimated. Changes in the various rates of the parameters due to environmental factors and management measures would affect the forecast. Long term frame surveys data were mapped on the digitized map of the East and West banks and compared.

Several assumptions were made to develop the model and these were due to the nature of the data. The main challenge faced in using GIS as a platform to investigate the fishery of Stratum VII of the Volta Lake was the lack of a system of data repository by appropriate institutions.

Conflict of Interests

The authors have not declared any conflict of interests.

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Effect of dietary protein levels on ammonia concentration and growth of *Tilapia rendalli* (Boulenger, 1896), raised in concrete tanks

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Tilapia rendalli **juveniles (±9.5 g) were cultured in concrete tanks to determine the effect of four dietary protein levels (30, 35, 40 and 45% crude protein (CP) in feed on ammonia concentration and growth performance of the fish, stocked at 15 fish per tank. Fish were monitored for a period of 90 days. Fish that were fed on 40% CP diet had significantly (P<0.05) higher weight gain, growth, and feed conversion ratio (FCR). Ammonia concentration was significantly higher (P<0.05) in tanks where the 45% CP diet was administered, and where also poor growth and survival rate was observed. Poor growth performance of the fish at inadequate (below 30% CP) and oversupply (above 40% CP) protein diet is evidence of the importance of taking precautions on the levels of protein inclusion in diet in tank culture. Higher dietary protein diet precipitates ammonia accumulation, thus compromising growth performance. Based on findings in this study, optimal protein level of 40% CP is recommended for tank culture.**

Key words: Ammonia concentration, dietary protein, growth performance, *Tilapia rendalli*.

INTRODUCTION

Tilapia rendalli (Red breasted tilapia) (Boulenger, 1896) is an important commercial species in sub Sahara Africa (Mair, 2001). It is the most commonly cultured species in Malawi alongside *Oreochromis shiranus*, *Oreochromis mossambicus* and *Oreochromis karongae.* The species is mostly preferred by farmers due to its flavour. *T. rendalli* is also the best candidate because it feeds on higher plants and has a reasonable growth rate when reared in extensive systems and supplemented with plant material compared to other species (Chikafumbwa, 1996). Chandrasoma and De Silva (1981) further observed that the length and weight at first maturity of *T. rendalli* varied from 18.8 to 25.8 cm and 126 to 380 g, respectively. Nyirenda et al. (2000) also observed that due to better growth performance, ability to breed, resistance to stress and marketing value, *T. rendalli* is ranked as the most potential cultured species for both commercial and small scale farming in Malawi. However, despite all advantages of *T. rendalli* over other species, little is known about *T. rendalli* nutritional requirement.

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Growth of fish in aquaculture systems depends on several factors, such as nutrition and the condition of water. Protein is the most essential nutrient component for growth performance, survival and yield of fish (Makwinja et al., 2013). On dry weight basis, protein makes up the maximum weight in fish body structure (Craig and Helfrich, 2009). Fish require protein for normal tissue function, maintenance and renewal of body protein and growth. However, because protein sources are costly, the fish need to utilise all protein provided in the diet for growth and muscle development. Furthermore, it is cost effective when protein is largely used for tissue repair and growth and less catabolised for energy (Gauquelina et al., 2007). Inadequate dietary protein in the diet reduces growth performance due to withdrawal of protein from less important tissue to maintain the functions of more important tissues (Halver, 1989). On the other hand, too much protein (above 40%) in the diet, results in only part being used to synthesise new proteins, while the rest is catabolised for energy (Alatise et al., 2006). Additionally, protein above 40% increases ammonia concentration in the culture systems.

Ammonia (NH_3) is a principle nitrogen excretory product of freshwater fish (Emerson et al., 1975). Its concentration in rearing tanks is due to end product of biological processes related with fish metabolism and is excreted mostly through the gills (Amoah, 2012). Large portion (over 80%) of the ammonia concentration in culture systems can also arise from the biological degradation of protein in waste feed and faeces by several genera of bacteria, including *Nitrosospira* and *Nitrosamines*. Other groups of bacteria, including *Nitrospira* and *Nitrobacter*, convert nitrite to nitrate (NO_3^-) (Tovar et al., 2000). Ammonia and its by-products are a major concern to fish health. Ammonia concentration above 0.05 mg/L may ultimately pollute the environment (Jindal et al., 2010) leading to multitude of symptoms and health problems in fish (Johnston, 2002). For instance, high concentration of ammonia (NH_3) (above 0.05 mg/L) in the culture water affects the diffusion gradient, which causes subsequent increase of ammonia concentration in the blood of the fish (Atle et al., 2003). Amoah (2012) observed that acute toxicity level of ammonia concentration (above 0.05 mg/L) in the tank systems can lead to hyper-ventilation, irregular swimming, convulsions and even death of the fish. This study was therefore designed to determine the effect of different protein levels in feed on ammonia concentration and growth of *T. rendalli* in concrete tanks.

MATERIALS AND METHODS

The study was conducted at the National Aquaculture Centre, Domasi, Southern Malawi (15°17'0" South and 35°24'0" East). The experiment was carried out in 1.5 m^3 concrete tanks laid out in a completely randomised design (CRD) with four dietary treatments (30, 35, 40, and 45% crude protein (CP)) replicated three times. The four dietary treatments were formulated using WinFeed version 2.8 (Mirza, 2004) by Linear Programming.

The ingredients (soybean, fish meal and maize bran) used in diet formulation were locally purchased from a local market in the area. Prior to formulation, the tested diets from each treatment were chemically analysed according to the standard methods of A.O.A.C (2003) for protein, fat, fibre and ash. In order to prepare diets, all the dietary ingredients formulations were finely ground and sieved using a 0.5 mm mesh size. Vitamin and mineral premixes, lysine and binders were included in the formulated diets at 0.2%.

To avoid contamination from previous feeds, the first feed from the metal die after a turn was discarded. The pellets obtained were then spread on a mat and sun-dried to constant weight for two to three days. The pellets were later broken down manually and sieved to bite size (0.1 and 0.2 mm) for fingerlings. All diets were labelled appropriately and packed in air-tight polyethylene bag and stored at a room temperature (25°C) for subsequent use.

A mixed sex *T. rendalli* juveniles of average body weight 9.8 g, were collected from National Aquaculture Centre Government Hatchery in Domasi, Zomba, Southern Malawi, during the month of October, 2014. The fingerlings were given a prophylactic treatment by immersing in salt (3% NaCl) solution for 10 min, to prevent spread and outbreak of viral, bacterial, fungal, and parasitic infections prior to introduction to growing tanks. During treatment, sufficient oxygen supply was maintained by changing and flushing out water frequently in the tanks. Before starting the experiment, the fish were acclimatised to the experimental condition for one week and fed on a commercial feed containing 25% CP.

T. rendalli juveniles were then stocked into 12 experimental tanks at 15 fish per 1.5 m^3 tank. Experimental diets (30, 35, 40 and 45% CP) were provided twice daily (10:00 and 15:00 h) for 90 days at 5% of fish live body weight. A record of supplied feed was kept for determination of feed conversion ratio (FCR) and protein efficiency ratio (PER).

Water quality parameters and ammonia

Water quality parameters in the tanks: temperature (Celsius thermometer), dissolved oxygen (Inolab Oxi Level 2 Oxygen metre), and pH (Suntex Model SP-701 pH metre), were monitored on daily basis at 8 am and 2 pm.

Ammonia was determined according to the EPA 350.1 and APHA 450-NH_3D methods (American Public Health Association, 2005). 500 ml of the reagent water was added to an 800 ml Kjeldahl flask. To reduce hydrolysis of cyanates and organic nitrogen compounds, 1 N NaOH was added to the 400 ml until the water sample was buffered at a pH of 9.5. 300 ml from the sample was distilled at the rate of 6 to 10 ml/min to form a solution of boric acid. Alkaline phenol and hypochlorite was added and reacted with ammonia to form indophenol blue that was proportional to the ammonia concentration. The blue colour formed was intensified with sodium nitroprusside and measured calorimetrically.

Fish sampling

Sampling was done every three weeks by catching the fish using a fine mesh scoop net, while removing excess water by gently blotting on a soft tissue paper. Fish were anaesthetized in crude clove powder (5 g/L) to reduce stress before weighing on Denver Instrument XL-3100 Scientific Balance Laboratory Scale. A sample of 30 fish was obtained from each treatment (10 fish from each replicate). Mortality of fish during the study period was recorded. After 90 days, fish were harvested and growth parameters were determined.

Growth evaluation

Weight gain, feed conversion ratio, specific growth rate, survival rate, protein index and condition factor were calculated according to Wang et al. (2005) as follows:

Weight gain (WG):

$$WG = W_f - W_{in} \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where WG = weight gain (g), W_f = final weight (g), W_{in} = initial weight (g)

Feed conversion ratio:

$$FCR = \frac{Total\,feed\,consumed\,by\,the\,fish\,(g)}{Weight\,gain\,by\,fish(g)} \ldots\ldots \quad (2)$$

Specific growth rate (SGR (% day^{-1})):

$$SGR = 100 * \frac{log_e W_f - log_e w_{in}}{period\,of\,culture\,(day)} \ldots\ldots \quad (3)$$

Where W_f = final weight (g), W_{in} = initial weight (g)

Survival rate:

$$Survival\,rate = 100 * {}^{N_f}/_{N_{in}} \ldots\ldots \quad (4)$$

where N_{in} = Number of fish at the start of the experiment, N_f = Number of fish at the end of experiment.

Nitrogen metabolism (NM) was calculated as (Jamabo and Alfred-Ockiya, 2008):

$$NM = [0.54](b - a)h]/2 \ldots\ldots \quad (5)$$

where a = initial weight (g), b = final weight (g), h = experimental duration (days).

Protein Index:

$$PI = [(survival\,rate * (BW_f(g) - BW_{in}(g))/_T \ldots\ldots \quad (6)$$

where PI = Protein index, BW_f = final body weight (g), BW_{in} = initial mean body weight (g), T = experimental duration (days).

Protein efficiency ratio:

$$PER = \frac{Wg\,(g)}{wp\,(g)} \ldots\ldots \quad (7)$$

where W_g = weight gain (g), W_{p} = weight of protein fed (g).

Condition factor (CF):

$$CF = \frac{W_2}{L_2^3} * 100 \ldots\ldots \quad (8)$$

where W_2 = final fish average weight (g), L_2 = average total length (cm^3)

Regression model

Third order polynomial regression model was used to describe the relationship between the growth parameters and the dietary protein levels. Similarly, the relationship between ammonia concentration and the dietary protein levels was described using third order polynomial regression model with the following empirical model of third order:

$$Y_i = \beta_0 + \beta_{1_{x_1}} + \beta_{1_{x^2_2}} + \beta_{1_{x^3_3}} + \epsilon_i \ldots\ldots \quad (9)$$

where Y= dependent variable, β_0 is the intercept and β_1, β_2, β_3,…, β_i are the regression coefficients of explanatory variables X_1, X_2, X_3,…, X_i and ϵ_i is random error or disturbance term.

Statistical analysis

The data was tested for normality using Shapiro-Wilk test and the homogeneity of variance using Levine's test for Equality of Variances in order to satisfy analysis of variance (ANOVA) assumptions. Percentage data, such as survival rate was first transformed using natural log and the results were reported as geometric mean after taking antilog. Statistical Package for Social Scientists (SPSS) software Version 16 for Windows was used for data analysis. Data were presented as mean ± standard error (SE) and the graphs were drawn by Microsoft Office Excel 2010.

All growth parameters were subjected to ANOVA to compare the means among the treatments at 5% level of confidence. The significant differences between the means were separated using least significant difference (LSD).

RESULTS

Water quality parameters and ammonia

Results for water physico-chemical parameters are shown in Table 1. The results revealed significant differences (P<0.05) in dissolved oxygen concentration among the treatments. The highest dissolved oxygen (7.5 mg/L) was recorded in the tank where fish were fed on 30% CP treatment and the lowest (7.2 mg/L) was recorded in 45%. There were no significant differences (P>0.05) in the mean temperature among the treatments. pH ranged from 8.4 to 8.8 among the treatments.

Ammonia concentration exhibited significant (P<0.05) differences among the treatments with the highest observed in 45% CP. A polynomial regression equation y = 2E-05x^3 - 0.0017x^2 + 0.028x, R^2 = 0.96 (Figure 1) showed that ammonia concentration increased with increase in dietary protein levels. Furthermore, the coefficient of polynomial regression model (R^2) revealed that 96% of variation in ammonia concentration was due to different dietary protein levels. The study recorded ammonia concentration of 0.014 mg/L in 30%, 0.02 mg/L in 35%, 0.023 mg/L in 40% and significantly (P<0.05) higher 0.13 mg/L in 45% treatment.

Growth parameters

Higher significant (P<0.05) average weight gain (ADG), specific growth rate (SGR), survival percentage, protein index (PI), nitrogen metabolism (NM) and better feed conversion ratio were recorded in the tank where fish were fed on 40% CP, while the fish fed on 45% CP treatment recorded the lowest (Table 2).

Polynomial regression equation (Y = -0.005x^3 + 0.35x^2 - 4.67x, r^2 = 0.98) (Figure 2) showed that 40% dietary

Table 1. Water quality parameters measured in tanks stocked with *Tilapia rendalli* for 90 days (mean ±SE).

Parameter	30% CP	35% CP	40% CP	45% CP	P value
PH range	8.6-8.9	8.4-8.5	8.7-8.8	8.3-8.4	
DO(mg/l)	7.5±0.0.2[d]	7.3±0.2[b]	7.29±0.02[b]	7.2±0.03[a]	0.038
Temp (°C)	24.25±0.1[a]	24.24±0.1[a]	24.30±0.03[a]	24.80±0.2[a]	0.065
Ammonia (mg/L)	0.01±0.03[a]	0.02±0.04[b]	0.02±0.01[b]	0.13±0.05[d]	0.001

Values with the same superscript in a row are not significantly different (P>0.05).

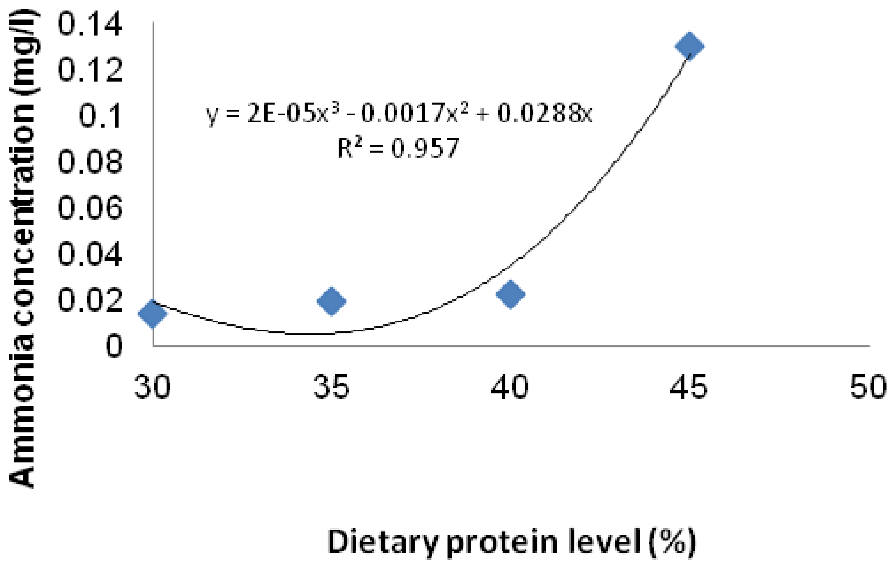

Figure 1. Relationship between ammonia concentration (mg/L) and dietary protein level for *Tilapia rendalli* raised in concrete tanks for 90 days.

Table 2. Growth and Feed conversion ratio of *Tilapia rendalli* raised in concrete tanks for 90 days (Results presented as mean ±SE).

Parameter	Treatments				
	30% CP	35% CP	40% CP	45% CP	P value
Initial weight (g)	9.77±0.02[a]	9.87±0.2[a]	9.53±0.23[a]	9.7±0.23[a]	0.783
Final weight (g)	46.6±0.49[b]	50.08±0.9[c]	53.93±0.93[d]	42.1±0.23[a]	0.001
Weight gain	36.9± 0.38[b]	40.5±0.8[c]	43 ±1.2[d]	32.4±0.76[a]	0.001
Feed conversion ratio	3.2±.0.03[c]	3.01±0.05[b]	2.9±0.05[a]	3.5±0.062[d]	0.001
Protein Efficiency ratio	0.7±0.04[b]	0.77±0.09[d]	0.72±0.1[c]	0.5±0.062[a]	0.001
Survival (%)	91±1.21[a]	92±0.15[b]	94±0.48[d]	83±0.02[c]	0.001
Condition factor (g/cm^{-3})	4.87±0.14[c]	5.02±0.15[d]	3.65±0.15[b]	0.19±0.01[a]	0.001
SGR (%day^{-1})	1.75±0.014[b]	1.83±0.027[c]	1.88±0.024[d]	1.64±0.016[a]	0.001
NM	894.97±0.3[b]	977.1±0.21[c]	1078.92±0.03[d]	787.32±0.04[a]	0.001
PI	0.36±0.08[b]	0.41±0.05[c]	0.46±0.02[d]	0.33±0.06[a]	0.001

Values with the same superscript in a row are not significantly different (P >0.05).

protein level was optimal. Additionally, the coefficient of polynomial regression model (R^2) explained that 98% of variation in final weight (g) was due to different dietary protein levels. Conversely, protein efficiency ratio (PER) and condition factor (CF) were the highest in 35% treatment and the lowest in 45% (Table 2).

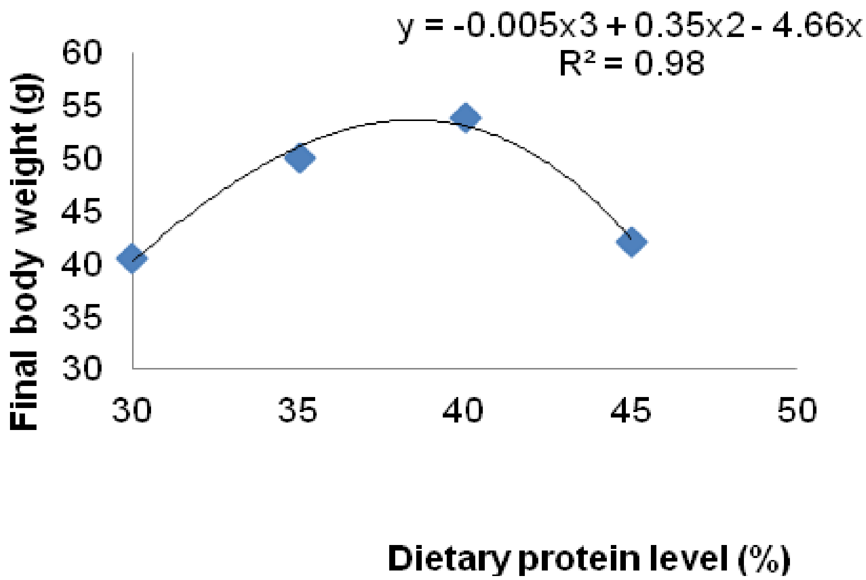

Figure 2. Relationship between final body weight and dietary protein level for *Tilapia rendalli* raised in concrete tanks for 90 days.

DISCUSSION

Water quality parameters, such as temperature, pH and dissolved oxygen (DO) were within the recommended range for the growth of most tilapias (Ross, 2000; Shepherd and Bromage, 1992). Ammonia concentration in 30, 35 and 40% treatments was within the recommended levels for optimum growth of tilapia (less than 0.05 mg/L) (Redner and Stickney, 1979). However, the ammonia level was the highest and above recommended value in 45% treatment. The highest ammonia concentration of 0.13 mg/L reported in 45% CP treatment could be attributed to endogenous ammonia which is related to higher quantity of nitrogen supplied by the 45% dietary protein levels (Thomas and Piedrahita, 1997).

Apparently, fish fed on 45% dietary protein may not have used all of the available protein, resulting into excessive ammonia accumulation in the tanks, as evidenced by lowest condition factor (0.19 g/cm^3) below recommended level which is above 1 g/cm^3 according to Mahomoud et al. (2011). These results agreed with Jindal et al. (2010) that excessive protein level in the diet increases nutrient retention in the culture systems. Furthermore, feed waste might have been as a result of poor assimilation. This suggests that at above 40% CP, the major portion (over 80%) of the nitrogen in the diet was added to the culture system, which ultimately polluted the environment. Lowest average weight gain (ADG), specific growth rate (SGR), protein index (PI) and nitrogen metabolism (NM) in the fish fed on 45% CP treatment could be due to the fact that highest ammonia level (0.13 mg/L) in 45% treatment might be toxic and eventually affecting growth of fish in the tanks as evidenced by low survival rate (83%) in 45% CP. Evidently, at high ammonia concentration (above 0.05 mg/L), metabolic rate is suppressed due to increased activity of glutamine synthesis, a detoxification mechanism (Mommsen et al., 1999). A glutamine synthesis is known to mediate the amination of glutamate and NH_3 in the formation of glutamine. Studies have shown that this pathway consumes vital brain ATP and glutamate resources, and can result in neurotransmission failure (Mommsen et al., 1999). This negatively affects growth performance. Poorer condition of the fish in the tanks was further evidenced by the lowest condition factor (0.19±0.01 g/cm^{-3}) observed in the fish fed on diet containing 45% treatment. The lowest condition factor indicated that the fish were affected by a number of factors, such as stress (Khallaf et al., 2003) attributed to high ammonia concentration.

In general, feed conversion ratio was reasonably high compared to the recommended rates (less than 2) in all treatments due to the fact that the feed might not have been palatable enough for the fish. Similar results were earlier reported for tilapia species (*Oreochromis niloticus*) by Abdel-Hakim et al. (2001). Nevertheless, feed conversion ratio (FCR) decreased with increasing dietary protein levels until the peak was reached at 40% CP and further increase in dietary protein levels resulted into decrease in FCR (Yang et al., 2002). Webster and Lim (2002) observed that better growth of fish relies on efficient synthesis of dietary protein into tissue protein.

The study further revealed that increase in the dietary protein level above 40% CP reduces protein efficiency ratio. Similar trend was earlier reported by Ahmad et al.

(2004) in tilapia species. The decrease in protein efficiency ratio at 45% dietary protein level might be attributed to the fact that beyond optimum point, more dietary protein is used as energy in the fish instead of being converted into muscle tissues (Kim et al., 1991).

The decrease in weight gain when feeding fish on the diet containing 45% dietary treatment could be due to the reduction in available energy for growth, because of inadequate non-protein energy necessary to deaminate and excrete excess absolute amino acids (Vergara et al., 1996). Too much protein in the diet may result into only a part being used to synthesise new proteins, while the rest is converted to energy (Alatise et al., 2006). When energy is in excess, fish may reduce feed intake thereby limiting the intake of amino acids needed for growth (NRC, 1993).

On the other hand, poor growth in the fish fed on 30% dietary treatment could be attributed to excessive carbohydrates in the diet which might have led to liver cell degeneration, hyperglycaemia and poor growth (Roberts, 1978; Halver, 1989). Furthermore, Makwinja et al. (2015) observed poor hepatosomatic index in the fish fed on 30% than the other treatments which suggested that low CP level in the diet correlate with reduction in available energy in the liver for growth.

Conclusion

This study has shown that in order to achieve acceptable fish growth, there is need to adopt optimal protein level of 40% CP. At 40% dietary protein, growth performance (weight gain, feed conversion ratio, specific growth rate) and water condition were within acceptable range for *T. rendalli* of the same size and resulted in high growth rate (1.88±0.024) compared to 30, 35 and 45% dietary protein levels. In conclusion, the suitability of 40% CP is in tank; however, studies should be conducted to investigate the suitability in other culture systems, such as earthen pond largely used by small scale farmers.

Conflict of Interests

The authors have not declared any conflict of interests.

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