COMPARATIVE EVALUATION OF THE PERFORMANCE OF NILE TILAPIA (*Oreochromis niloticus*) CULTURED UNDER DIFFERENT CLIMATIC CONDITIONS IN TANZANIA

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EXTENDED ABSTRACT

Growth performance and productivity of Nile tilapia (*Oreochromis niloticus)* is highly influenced by water quality in the pond. On the other hand, water quality is influenced by the climate and ecological conditions of the place. This study evaluated the growthperformance, survival rate, yield, body length-weight relationship and condition factor of Nile tilapia (*Oreochromis niloticus)* cultured in two districts; Mbarali and Mufindiof Mbeya and Iringa regions,respectively. Furthermore, plankton biomass yield, species composition and biochemical composition of the algae collected from the ponds located in these two districts were assessed. The two districts experience different ecological conditions withhigh and low temperatures.In each district fish were raised in four earthen ponds,each with an average size of 650 m^2 for six months. There were two sites per district and two ponds in each site. All ponds were initially drained, cleaned, dried and refilled with water. The ponds were fertilized seven days prior to stocking using urea and Diammonium phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2,respectively.Thereafter, fertilization was done fortnightly throughout the experimental period. Sex reversed Nile tilapia fingerlings with an average body weight of 1.00 g were stocked at a stocking density of 2 fingerlings/m^2. Fish were fed with supplementary diet containing 25% crude protein (CP) at 10% of fish body weight in the first month, followed by 5% for the remaining five months. Feeding was done twice daily, at 10.00 to 10.30 am and at04.00 to 04.30 pm. Body weight, length, width and water quality parameters,namelytemperature, dissolved oxygen, transparency, conductivity, salinity, alkalinity, ammonia, nitrate and phosphorus were measured biweekly. Analysis of variance (ANOVA) was used to test the effect of location on growth performance and water quality parameters. Duncan's New Multiple Range test was used to test the significance of the differences between a pair of treatment means. The relationships

between fish growth and water quality parameters were assessed using correlation analysis while multiple regression analysis was used to assess the influence of water quality parameters on fish growth. All statistical analyses were performed using the General Linear Model (GLM) of the Statistical Analysis System software (SAS, 2000) for Windows. Significant differences were judged at a probability level of $p \leq 0.05$.

Results revealed that, the growth performance of sex-reversed Nile tilapia was higher ($p<0.05$) in Mbarali than in Mufindi district where there was high temperature and low temperature, respectively. The mean growth rate (1.26 ± 0.03 g/day), specific growth rate (3.12 ± 0.02%), mean final weight (228.68 ± 4.99 g) and estimated annual yield (6828.43 ± 407.95 kg/ha/year) obtained from the Nile tilapia (*Oreochromis niloticus*) cultured at Mbarali district were significantly higher than of those reared in Mufindi district (mean growth rate = 0.48 ± 0.03 g/day, specific growth rate = 2.52 ± 0.02%, mean final weight = 86.68 ± 4.79 g and estimated annual yield = 4465.29 ± 407.95 kg/ha/year). Mean final body length and width were also higher for the fishgrown in ponds located at Mbarali (body length = 21.87 ± 0.16 cm and width = 7.71 ± 0.07 cm) than of those grown at Mufindi (body length = 16.14 ± 0.15 cm and width = 5.55 ± 0.07 cm).

The results further revealed that, water quality parameters (temperature, salinity, conductivityand alkalinity) were higher in ponds located at Mbarali than in those located at Mufindi district ($p< 0.05$) while water transparency was significantly higherin ponds located at Mufindi compared to that of those located at Mbarali. The mean temperature, dissolved oxygen (DO), pH, conductivity, salinity, transparency, phosphorusand nitrate in Mbarali were 27.72 ± 0.25 ^{0}C, 6.17 ± 0.27mg/L, 6.91 ± 0.15, 121.62 ±3.27 µS/cm, 57.35 ± 1.86 mg/L, 15.73 ± 0.56cm, 1.33 ± 0.17mg/L, and 7.72 mg/L, respectively. The mean temperature, dissolved oxygen (DO), pH, conductivity, salinity, transparency,

phosphorusand nitrate in Mufindi were 21.93 ± 0.25 ^{0}C, 6.09 ± 0.27 mg/L, 6.96 ± 0.15, 31.81 ± 3.27 µS/cm, 13.18 ± 1.86mg/L, 17.25 ± 0.56 cm, 0.98 ± 0.17 mg/Land 7.71 ± 0.24 mg/L,respectively. Regression of water quality parameters on growth showed that DO and transparency had significant positive influence only for fish growth at Mbarali while temperature and conductivity had positive and significant influence on the growth of fish at Mufindi district.

The correlation coefficients (r) between weight and length in both experimental locations were above 95%, indicating a strong relationship between live weight and body length of the fish. The regression coefficient (b) values in the length-weight relationships were 2.87 and 2.94 for Mbarali and Mufindi, respectively, indicating negative allometric growth. The mean condition factor (K) values ranged from 2.74 to 3.50 for Mbarali and 1.96 to 2.40 in Mufindi. The exponential value 'b' and the condition factor (K) differed significantly between the two experimental locations ($p< 0.05$).

The analysis of plankton species composition revealed no significanctdifference in number of species found in experimental ponds located in the two locations ($p> 0.05$). Common species found in both locations belonged to the following classes; *Bacillarophyceae, Chlorophyceae, Cynophyceae, Euglenoidea, Foraminifera, Heterotrichea*, *Monogononta*, *Tubulinea and Zygnemaphyceae*.The class *Eurotatoria* was found only at Mufindi district. Algal samples collected from Mbarali had higher ($p \leq 0.05$) biomass (51.74 ± 1.83 g DM/m^2) and crude protein (CP) (16.46 ± 0.65%) contents compared to those collected from Mufindi (biomass = 39.25 ± 1.83 g DM/m^2, CP = 14.44 ± 0.65%).From the results of this study it is concluded that, differences in climatic conditions between experimental locations influence significantly the production performance, length-weight relationship and condition factor of Nile tilapia. Plankton

species composition, chemical compositions differ slightly between the two experimental locations.

DECLARATION

I, EMMA ABEL KOMBA, dohereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

_____ _____

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The above declaration is confirmed by;

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Prof. Chenyambuga, S. W. Date

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Dr. Munubi, R. N. Date

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA Analysis of Variance

AOAC	Association of Official Analytical Chemists
ADG	Average Daily Gain
cm	Centimetre
CP	Crude Protein
DAP	Diamonium Phosphate
DM	Dry Matter
DO	Dissolved Oxygen
EE	Ether Extract
FAO	Food and Agriculture Organization of the United Nations
FCE	Feed Conversion Efficiency
FCR	Feed Conversion Ratio
FI	Feed Intake
FnBW	Final Body Weight
FnBWd	Final Body Width
FnBL	Final Body Length
g	Gram
GLM	General Linear Model
GR	Growth Rate
h	Hour
ha	Hectare
InBW	Initial Body Weight
InBL	Initial Body Length
InBWd	Initial Body Width
K	Condition factor
kg	Kilogram

L	Litre
LG	Length Gain
LSM	Least Square Mean
LWR	Length Weight Relationship
m	Metre
mg	Milligram
ml	Millimetre
MSc	Master of Science
NH_4^+	Ammonium
NO_3	Nitrate
p	Probability
P	Phosphorous
pH	Hydrogen ion concentration
PSU	Practical Salinity Unity
rpm	Revolution per minute
SAS	Statistical Analysis System
SE	Standard Error
SGR	Specific Growth Rate
SR	Survival Rate
SUA	Sokoine University of Agriculture
T	Time
TL	Total Length
WG	Weight Gain
WdG	Width Gain
WL	Water Level

%	Percentage
^{0}C	Degree Celsius

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Aquaculture is one of the fastest growing food production sectors in the world.It supplies about half of the world fish and plays an important role in reduction of poverty, providing employment opportunities and ensuring food security (FAO, 2010). Nile tilapia (*Oreochromis niloticus)* is one of the most cultured and popular species in aquaculture production and it has been introduced in many countries around the world (FAO, 2010; Friedman *et al*., 2011).

Nile tilapia possess a number of good characters including ability to tolerate a wide range of environmental conditions, fast growth, better food utilization efficiency, good fecundity and acceptable flesh quality. These are among the many good farming qualities which makes tilapia to be the species of choice for culture in many areas (Bhujel, 2013; Jamil *et al*., 2004; Opiyo *et al*., 2014; Neves *et al*., 2008).

Despite the ability to survive in a wide range of environmental conditions, productive performance (growth rate, yield, survival and reproduction) of Nile tilapia vary from place to place or time to time due to differences in environmental conditions in which they are cultured. Climatic conditions of the area play an important role in influencing water quality parameters such as temperature, salinity, pH, evaporation, dissolved oxygen, conductivity and alkalinity which, in turn, influence the growth and survival of cultured Nile tilapia (Schofield *et al.,* 2011). Optimal production can be achieved only when the water quality parameters are within the tolerable limits (Siddik *et al*., 2014; Ulotu *et al*., 2016).

1.1.1 Tilapia farming in Tanzania

In Tanzania, aquaculture is one of the most important socio-economic sub-sectors,which provide employment, food security, income, livelihood, foreign earnings and revenue to the country (Kaliba *et al*., 2006). The demand for fish food is increasing from day to day possibly due to increasing population growth, economic development and changes in eating habits. The supply of fish comes from two main sources; namely captive fisheries based on natural water bodies and aquaculture. Like in many other countries around the world, in Tanzania, Nile tilapia (*Oreochromis niloticus*) is the most cultured freshwater species among the different farmed fish species (Santos *et al*., 2013). It is commonly cultured in earthen ponds under mixed sex culture in intensive, semi-intensive and extensive systems (Jaspe and Caipang, 2011; Kaliba *et al*., 2006). However, in recent years, production of single sex male Nile tilapia has been promoted and practiced by few farmers.

1.1.2 Water quality and Nile tilapia

Water quality is a primary determinant of survival, growth and reproduction of Nile tilapia. In general, water quality parameters can be categorized as physical, chemical and biological qualities.The physical water quality parameters are such as temperature, turbidity, colour and salinity; chemical qualities are such as dissolved oxygen, pH, dissolved gases, conductivity, dissolved cations and anions while the biological qualities are living organisms which including phytoplankton and zooplankton populations (Bhatnagar and Devi, 2013).It is well established that, optimal productivity is achieved when these water quality parameters do not exceed tolerable limits. Extreme changes in water quality parameters either below or above the tolerable limits may cause adverse effect on fish body physiology and survival, resulting in poor growth and reduction in yields (Begum *et al.*, 2014; Celik, 2012). For that reason, proper monitoring of water

quality parameters in culture facilities is necessary to ensure that the parameters are maintained at ideal levels.

Table 1: Suggested water-quality criteria for pond water fishery for getting high yield via applying minimum input (Bhatnagar and Devi, 2013)

S/N	Parameter	Acceptable range	Desirable range	Stress
1	Temperature (0C)	15 - 35	20 - 30	<12, >35
2	Turbidity (cm)		30 - 80	<12, >80
3	Water colour	Pale to light green	Light green to light brown	Clear water, Dark green &Brown
4	Dissolved oxygen (mg L^{-1})	3 - 5	5	<5, >8
5	CO_2 (mg L^{-1})	0 - 10	<5, 5 - 8	>12
6	pH	7 – 9.5	6.5 - 9	<4, >11
7	Alkalinity (mg L_{-1})	50 - 200	25 - 100	<20, >300
8	Hardness (mg L^{-1})	>20	75 - 150	<20, >300
9	Calcium (mg L^{-1})	4 - 160	25 – 100	<10, >250
10	Ammonia (mg L^{-1})	0 – 0.05	0 - <0.025	>0.3
11	Nitrite (mg L^{-1})	0.02 - 2	<0.02	>0.2
12	Nitrate (mg L^{-1})	0 - 100	0.1 – 4.5	>100, <0.01
13	Phosphorus (mg L^{-1})	0.03 - 2	0.01 – 3	>3

1.1.3 Effects of climatic conditions on water quality and performance of Nile tilapia

Climate plays an important role in aquaculture. Climatic parameters like amount of rainfall, solar radiation, evaporation and temperature tend to influence water quality variables and subsequent performance of tilapia. Variation in pond water temperature is due to differences in the amount of radiation received, which in turn, varies with latitudes, altitude and seasons of the year. Temperature influences water density, which creates neutral form of water circulation (Sriyasak *et al*., 2013). Solar radiation also plays a vital role in photosynthesis which again affects other variables like primary productivity, oxygen level, pH and carbon dioxide concentration in water (Adeleke and Omoboyeje, 2016). As temperature increases, the rate of bio-chemical activity of the micro-biota, plant respiratory rate increases thus, increasing oxygen demand. It further reduces solubility of

oxygen and escalates the solubility of many toxic substances such as cyanides, phenol, xylene, ammonia and zinc in water (Begum *et al.,* 2014; Bhatnagar and Devi, 2013). Water temperature also affects viscosity, which, in turn, affects ionic activity and conductivity. There is an inverse relationship between temperature and viscosity; this means that an increase in temperature will decrease viscosity. A decrease in viscosity of water increases the mobility of ions in water. Thus, an increase in temperature increases conductivity (Miller *et al*., 1988; Wetzel, 2001).

1.1.4Length weight relationship and condition factor

Like in many other organisms, growth in fish occurs in various patterns. Fishes exhibit both isometric and allometric growth pattern (Olopade, 2015). The fish is said to exhibit isometric growth when length increases in equal proportion with body weight. The regression coefficient for isometric growth is '3' and values greater or less than '3' indicates allometric growth pattern (Olurin and Aderibigbe, 2006).

The uses of biometric relationships are often required in order to transform data collected in the field into appropriate indexes. Length-weight relationship (LWR) is one of the most commonly used relationships in analysis of fishery data. The LWR helps in estimation of the biomass from known length (Muchlisin *et al.*, 2017). It also provides information on the condition factor which indicates the "wellbeing of the fish" (Keyombe*et al*., 2017).

The condition factor is an index reflecting interaction between biotic and abiotic factors in the physiological conditions of fish in relation to its welfare. Therefore, this factor may vary according to the influences of physiologic factors, environmental conditions, time and stages of development (Blackweel *et al.,* 2000; Moutopoulos and Stergiou, 2002). A higher value of condition factor reflects better condition attained by the fish (Abdoli and

Rasooli, 2008). It is also a useful index for monitoring feeding intensity, age, mortality, life span, growth rates and reproduction in fish (Kumar *et al.*, 2014; Ujjania *et al*., 2012).

1.1.5 Algal biomass, species and biochemical composition

Plankton are a large and highly diverse group of organisms which can be found in almost all earth ecosystems, aquatic and terrestrial ecosystem (Raja *et al*., 2008; Selvarajan *et al*., 2015). Plankton can be subdivided into two groups; eukaryotic (e.g. green algae) and prokaryotic algae (e.g. Cyanobacteria) (Richmond, 2004). Planktons play important roles in aquaculture, their main functions being related directly or indirectly to the nutrition of fish and water quality. They have ability to convert light energy and carbon dioxide (CO_2) into biomass (e.g. carbohydrates, proteins and lipids) through photosynthesis process (Karthikeyan, 2012; Nihed, 2017; Park *et al*., 2011).

Generally, planktons are considered as important primary food producers, providing essential nutrients for aquatic ecosystem in aquatic food chain (Raja *et al*., 2008). They can be used directly as food by some fish species or indirectly, as food for zooplankton such as rotifers which are essential source of food for fish (Brown and Robert, 2002; Muller-Feuga, 2000; Welladsen *et al*., 2014).

For that reason, plankton species composition and abundance, biomass and biochemical compositions directly affects the nutrition, growth, reproduction and survival of fish in a pond (Egerton and Marshall, 2014). Plankton growth, species composition, biomass and biochemical composition depends on the environmental factors such as temperature, light and nutrient availability (Keys*et al*., 2018; Sandnes *et al.*, 2005).The quality of planktons varies with species and strains as well as the environmental conditions (Juneja *et al*., 2013; Sun *et al*., 2015).

1.2 Justification of the Study

Production performance of Nile tilapia and their growth patterns are highly influenced by the environmental factors of the culture system such as fish pond. Physico-chemical and biological qualities of pond water are the main influencing factors. Apart from supplementary feed provided to fish, planktons in fish pond provide fish with essential natural feed that improve fish growth and reduce production costs in terms of food costs. However, water quality parameters and plankton biomass, species and biochemical compositions tend to vary depending on the climate and ecological nature of the environment in which the fish are grown (e.g. duration and quality of sunlight, temperature, relative humidity, evaporation, precipitation, topography of lands, nutrients and carbon sources). Consequently, fish productivity and condition factor differ from place to place, possibly as a result of changes in environmental conditions.

However, information on which specific climatic conditions favour high productivity of Nile tilapiain Tanzania is missing. The Nile tilapia has been introduced in all agro-ecological zones in the country without taking into consideration the ideal environmental conditions for their optimal growth. For that reason, it is crucial to carry out a study to evaluate the production performance of Nile tilapia raised in different ecological conditions in order to determine the most appropriate agro-ecological zone for growing Nile tilapia in the country.

1.3 Objectives

1.3.1 General objective

The overall objective of this study was to assess the production performance of Nile tilapia (*Oreochromis niloticus*) under two different climatic conditions in Tanzania.

1.3.2 Specific objectives

The study was designed to address the following specific objectives:-

i. To compare water quality parameters and growth performance of sex-reversed Nile tilapia (*Oreochromis niloticus)* reared in two districts which experience different climatic conditions in Tanzania.

ii. To evaluate weight-length relationship and condition factor of Nile tilapia (*Oreochromis niloticus*) cultured in two districts which experience different climatic conditions in Tanzania.

iii. To determine biomass yield, species and biochemical compositions of plankton collected from fish ponds located in two districts which experience different climatic conditions in Tanzania.

1.4 Null Hypothesis

i. There are no significant differences in production performance, Length-Weight relationship and condition factor of sex-reversed Nile tilapia (*Oreochromis niloticus*) reared under two districts experiencing different climate conditions.

ii. The water quality parameters and phytoplankton biomass yield, species and chemical compositions are not significantly different between the two sites experiencing different climate conditions.

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CHAPER TWO

MANUSCRIPT – I

COMPARATIVE EVALUATION OF WATER QUALITY PARAMETERS AND GROWTH PERFORMANCE OF SEX-REVERSED NILE TILAPIA (*Oreochromis niloticus*) RAISED IN TWO DIFFERENT ECOLOGICAL CONDITIONS IN TANZANIA

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ABSTRACT

A study was carried out to compare water quality parameters, growth performance, survival rate and yield of sex-reversed Nile tilapia (*Oreochromis niloticus)* cultured in two districts of Tanzania, which experience different climatic conditions. The districts were Mufindi which has cold environmental condition and Mbarali where the condition is moderately warm. Sex-reversed Nile tilapia fingerlings with an average weight of 1.00 g were stocked in eight earthen ponds with an average size of 650 m^2. Four ponds were located in Mufindi and the other four ponds were located in Mbarali. All ponds were fertilized seven days prior to stocking, and then fortnightly throughout the experimental period using urea and Diammonium phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2,respectively. The fish were supplemented with a diet containing 25% crude protein (CP) at a feeding rate of 10% of fish body weight during the first month and 5% for the remaining five months of the experiment. Body weight, length and width were measured

biweekly alongside with measurement of physico-chemical water quality parameters. The experiment lasted for six months.

Results revealed that, sex-reversed Nile tilapia performed better in the area with high temperature (Mbarali district) than in the area with low temperature (Mufindi district). Nile tilapia cultured in ponds located at Mbarali district had significantly higher ($p \leq 0.05$) mean growth rate (1.26 ± 0.03 g/day), specific growth rate ($3.12 \pm 0.02\%$), mean final weight (228.68 ± 4.99 g) and estimated annual yield (6828.43 ± 407.95 kg/ha/year) than those cultured at Mufindi district which had mean growth rate of 0.48 ± 0.03 g/day, mean specific growth rate of $2.52 \pm 0.02\%$, mean final weight of 86.68 ± 4.79 g and estimated mean annual yield of 4465.29 ± 407.95 kg/ha/year. Mean final body length (21.87 ± 0.16 cm) and width (7.71 ± 0.07 cm) were also higher ($p \leq 0.05$) for the fishgrown at Mbarali than of those grown at Mufindi (16.14 ± 0.15 cm final body length and 5.55 ± 0.07 cm final width). Fish raised in Mbarali had significant better ($p = 0.0069$) mean Feed Conversion Ratio (FCR) of 1.49 ± 0.06 than those grown at Mufindi with FCR of 2.16 ± 0.06.

Temperature ($27.72 \pm 0.25\ ^{0}C$), salinity ($57.35 \pm 1.86\ mgL^{-1}$), conductivity ($121.62 \pm 3.27\ \mu Scm^{-1}$) and alkalinity ($105.30 \pm 4.27\ mgCaCO_3L^{-1}$)weresignificantly higher ($p \leq 0.05$) for ponds located in Mbarali compared to those at Mufindi district (temperature = $21.93 \pm 0.25\ ^{0}C$, salinity = $13.18 \pm 1.86\ mgL^{-1}$, conductivity = $31.81 \pm 3.27\ \mu Scm^{-1}$and alkalinity = $82.39 \pm 4.27\ mgCaCO_3L^{-1}$).

Regression of water quality parameters on growth showed that DO and transparency had significant positive influence only for fish growth at Mbarali while temperature and conductivity significantly influenced positively the growth of fish at Mufindi district. It is

concluded that, growth performance and FCR were better for Nile tilapia grown at Mbarali where temperaturewas within the acceptable range than for those grown at Mufindi where temperature was low.

Keywords: *Annual yield, growth rate, physico-chemical water quality parameters, specific growth rate, survival rate.*

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is one of the mostimportant cultured and popular species in aquaculture production in Tanzania and other many countries around the world (FAO, 2010; Kaliba *et al*., 2006). In many developing countries, it is mainly cultured in earthen ponds or cages under mixed-sex culture system, both extensively and semi-intensively (El-Sayed, 2006). High growth rate, tolerance to wide range of environmental conditions, high food utilization efficiency, good fecundity and good flesh quality are among the many good farming qualities which make tilapia to be the species of choice for aquaculture in many areas (Jamil *et al*., 2004; Neves *et al*., 2008).

Despite its ability to survive in a wide range of environmental conditions, production performance of Nile tilapia vary considerably from place to place or time to time due to changes in quality of environmental conditions (biological, chemical and physical environment) in which they are cultured (Bhatnagar and Devi, 2013; Ulotu *et al*., 2016). For proper survival, optimum growth and production of Nile tilapia the water quality parameters must be maintained within the tolerable limits. Good water quality is characterised by proper levels of dissolved oxygen, pH, temperature, salinity, transparency, limited levels of metabolites and other environmental factors affecting fish growth (El-Sherif and El-Feky, 2009). Any change in water quality parameters beyond the tolerable limits add stress to the fish and affect productivity.

Climatic conditions of the area play an important role in influencing water quality parameters such as temperature, salinity, pH, evaporation and dissolved oxygen, which, in turn, influence the growth and survival of cultured Nile tilapia (Schofield *et al.,* 2011). Like other countries, Tanzania exhibits different ecological conditions in different places around the country. These differences in climatological factors influence water quality parameters, hence, aquatic life. This study intended to compare pond water quality parameters and the performance (growth rate, feed conversion efficiency, survival rate and production yield and FCR) of Nile tilapia (*Oreochromis niloticus*) cultured in two different climatic conditions in Tanzania i.e. low temperature and moderately high temperature.

MATERIALS AND METHODS

Experimental location

The study was conducted in two districts located in different regions of Tanzania; Mufindi district in Iringa region and Mbarali district in Mbeya region. Mufindi district lies between latitude 8^0.00' – 9^0.15' S and longitude 34^0 35' – 35^0 55'E. The mean annual rainfall ranges between 950 and 1600 mm. The mean maximum temperature is 18.4 ^{0}C (between November and February) and the minimum is 13.1 ^{0}C (July). The altitude ranges from 1700 to 2200 m above sea level (Nuru, 2013). Mbarali district is located between latitude 7^0 and 9^0 S and between longitude 33.8^0 and 35^0 E. The altitude ranges from 1000 to 1800 meters above sea level. Average temperature ranges between 25 and 30 ^{0}C. The annual rainfall is about 450 to 650 mm (Chenyambuga *et al*., 2014). In each district, two sites were selected and at each site there were two ponds used for this experiment.

Pond Preparation, Stocking and Management

Fingerlings of sex-reversed male Nile tilapia (*Oreochromis niloticus*) with an average weight of approximately 1.00 g. were used in this study. The fingerlings were obtained from Ruvu Fish Farm located at Kibaha district, Coast region, Tanzania. A total of eight ponds with an average size of 650 m^2 were used. Four ponds were located at Mufundi district and the other four ponds were located in Mbarali district. Before stocking, all ponds were drained, cleaned, dried and left for seven days before being refilled with water. All ponds were initially fertilized and left for seven days prior to stocking, using urea and Diamonium Phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2, respectively. During the experimental period all ponds were fertilized fortnightly with the same fertilizers and at the same rates. Sex reversed male Nile tilapia (*Oreochromis niloticus*) fingerlings were stocked at a stocking density of 2 $fish/m^2$. Fish were fed with a supplementary diet twice daily; in the morning at 1000 to 1030 h and in the evening at 1600to 1630 h. The diet contained 25% Crude protein (CP) formulated using maize bran (50%), fish meal (25%), cotton seed cake (10%), sunflower seed cake (10%), maize meal (4%) and mineral premix (1%). Fish were fed at a level of 10% of their body weight during the first month, followed by 5% of body weight for the remaining five months of the experimental period. The fish were acclimatized for two weeks and during the last three days initial weights were measured.

Sampling, Data collection and Analysis

Body weight, total length (TL) and width were measured fortnightly throughout the experimental period alongside with measurement of physico-chemical water quality parameters. For measuring body weight, length and width, a sample of 50 fish from each pond was randomly collected and measured. Body weight was measured using a sensitive weighing balance and recorded to the nearest 0.01 g while the TL (cm) and width (cm)

were measured to the nearest 0.1 cm using a measuring ruler. All measurements were done between 0800 h and 0900 h prior to feeding. All fish deaths observed during the experimental period were counted and recorded. At the end of the experiment, fish were harvested by repeated netting using a seine net 1.5 x 15 m with 2cm mesh size, counted and measured. The data on body weight were subjected to the following formulae for growth performance and survival rates calculations as recommended by Khater (2017); Mbiru *et al*. (2015) and Opiyo *et al*. (2014).

$$\text{Daily Weight Gain (DWG)} = \frac{\text{Final weight (g)} - \text{initial weight (g)]}}{\text{Time (days)}} \quad (1)$$

$$\text{Specific Growth Rate (SGR)} = \frac{[\text{In(Final weight (g)} - [\text{In(initial weight (g)]}}{\text{Time (days)}} \text{ X } 100 \quad (2)$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Amount of feed consumed (g DM)}}{\text{Weight gain (g)}} (3)$$

$$\text{Survival Rate (SR)} = \frac{\text{Total number stocked} - \text{total number died}}{\text{Total number stocked}} \text{ X } 100 \quad (4)$$

$$\text{Fish yield (kg/ha/year)} = \frac{\text{Weight of fish harvested (kg/ha)}}{\text{Experimental period (days)}} \text{x } 365 \text{ days} \quad (5)$$

Determination of water quality parameters

Water quality parameters i.e. water temperature, dissolved oxygen, pH, salinity, conductivity, nitrate-nitrogen, ammonia-nitrogen, total alkalinity and phosphorus were measured at two weeks interval. Water, temperature (^{0}C), dissolved oxygen (mgL^{-1}), pH, conductivity (µScm^{-1})and salinity were measured by using DO meter (HI 98198 PH/EC/DO Multiparameter HANNA instruments). Measurements were done at three depths; top, middle and bottom of the pond water, then the average values of the three depths were computed. Water samples from the three depths were collected using plastic containers of 500 ml, thoroughly mixed to homogenize and then preserved at $^-18^0$C for

laboratory analysis of Nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate-phosphorus (PO_4-P). NO_3-N and NH_3-N were determined using Kjeldahl method while PO_4-P was determined by spectrophotometry following standard procedures (Asuero *et al.*, 2013).

Data analysis

Descriptive statistics were computed to get mean and standard error of fish body weight, width and length and water quality parameters. Analysis of variance (ANOVA) was used to test the effect of location (climate) on growth performance and water quality parameters. Duncan's New Multiple Range test was used to determine the significance of the differences between a pair of treatment means. The influence of each water quality parameter on fish growth was assessed using multiple regression analyses. All statistical analyses were performed using the General Linear Model (GLM) of the Statistical Analysis System software (SAS, 2000) for Windows. In the analysis of variance, initial weight was included in the model as a covariate. Significant differences were judged at a probability level of $p \leq 0.05$.

The model used to analyse the data was;

$$Y_{ijk} = \mu + L_i + S(L)_j + b(x_{ij} - X)_k + e_{ijk}$$

Where: μ = Overall mean; L =Effect due to location; S $(L)_j$ = effect of site within a location; $b(X_{ij}-X)$ = regression of Y_{ij} on the initial body weight; X_{ij} = Initial body weight; X = Initial mean weight and e_{ijk} = Error term

The model for multiple regression analysis was:

$$Y_{ij} = \mu + Q_i + e_{jk}$$

Where: Y_{ij} =Final weight= μ = Overall mean, Q_i= water quality parameters, e_{ij}= Error term

RESULTS

Pond water quality parameters

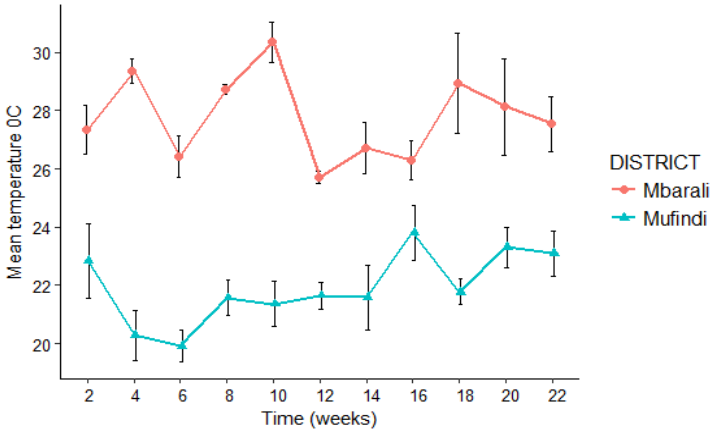
The least squares means (LSM) for water quality parameters measured in this study (i.e. water temperature, pH, dissolved oxygen, alkalinity, conductivity, transparency, ammonia, nitrate and phosphorus) are presented in Table 1.The results show that water temperature, salinity, conductivity and alkalinity differed significantly between the two locations ($p \leq 0.05$). The pond water in Mbarali had significantly higher values for temperature, salinity, conductivity and alkalinity compared to those in Mufindi (Table 1). The values for DO, pH, nitrate, ammonia,water transparency and phosphorus did not differ ($p > 0.05$) between the two locations. Results also showed that, pond water temperatures in Mbarali and Mufindi were significantly different while pH and DO did not differ significantly throughout the experimental period (Figure1).

Table 1: Comparison of water quality parameters (LSM ± SE) in ponds located inMbarali and Mufindi districts

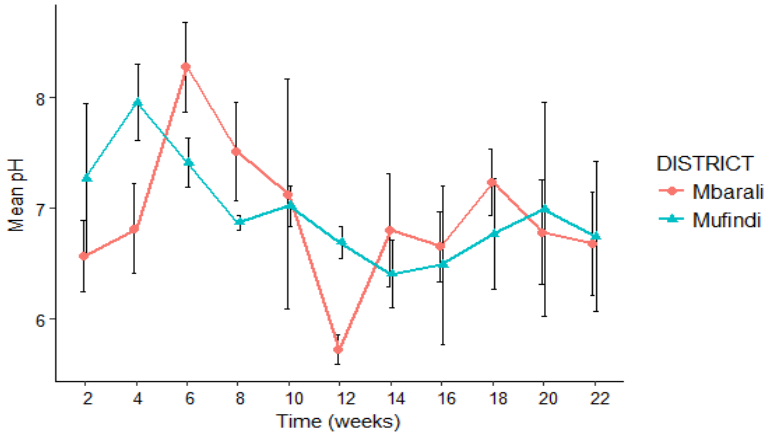
Variables	Locations		p Value
	Mbarali	Mufindi	
Temperature ^{0}C	27.72 ± 0.25^a	21.93 ± 0.25^b	<.0001
pH	6.91 ± 0.15^a	6.96 ± 0.15^a	0.8081
Dissolved oxygen (mgL^{-1})	6.17 ± 0.27^a	6.09 ± 0.27^a	0.8284
Salinity (mgL^{-1})	57.35 ± 1.86^a	13.18 ± 1.86^b	<.0001
Conductivity (µScm^{-1})	121.62 ±3.27^a	31.81 ± 3.27^b	<.0001
Transparency (cm)	15.73 ± 0.56^a	17.25 ± 0.56^a	0.0597
Ammonia(mgL^{-1})	0.08 ± 0.19^a	0.07 ± 0.19^b	0.0625
Nitrate(mgL^{-1})	7.72 ± 0.25^a	7.71 ± 0.24^a	0.9629
Phosphorus (mgL^{-1})	1.33 ± 0.17^a	0.98 ± 0.17^a	0.1444
Alkalinity (mgCaCO3$^-$L)	105.30 ± 4.27^a	82.39 ± 4.27^b	0.0003

*^{ab}= *Means with the same superscript letter in the same row do not differ significantly (*p>*0.05).*

(a)



(b)



(c)

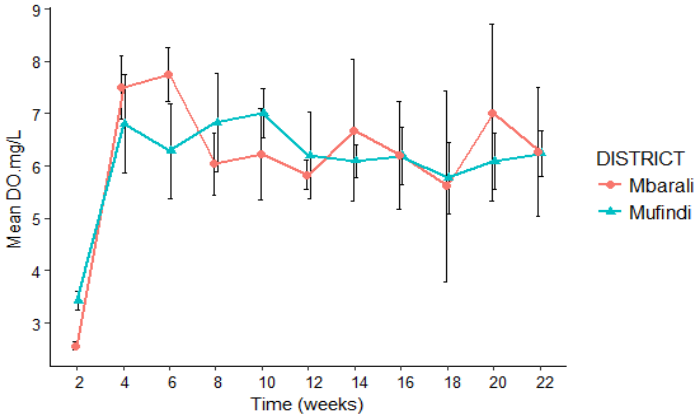


Figure 1: Comparison of water temperature (a), pH (b) and dissolved oxygen (c) from fish ponds located at Mbarali and Mufindi districts

Influence of water quality parameters on fish growth performance

The results for multiple regression analysis indicated that among the water quality parameters analysed, ammonia levelsaffected significantly the growth of fish in both districts. Water temperature, DO and conductivity had positive influences on the growth of fish in both districts. However, NH_4-N, NO_3-N and alkalinity had negative influence on fish growth in both districts. The influence of each water quality parameter on the growth of fish in each experimental location is summarized in Table 3.

Table 2: Regression on the influence of water quality parameters on fish growth

	Mbarali			**Mufindi**		
Parameter	Estimate (b)	SE of the estimate	p-value	Estimate (b)	SE of the estimate	p-value
Temperature ^{0}C	9.49	6.91	0.1773	3.25	1.54	0.0409
pH	9.18	13.94	0.5140	-3.67	2.94	0.2181
Dissolved O_2(mgL^{-1})	16.85	6.12	0.0087	0.29	2.00	0.8844
NH_4-N (mgL^{-1})	-30.19	10.89	0.0083	-7.06	2.13	0.0019
NO_3-N(mgL^{-1})	-15.92	7.61	0.0424	-1.97	2.07	0.3471
Alkalinity(mgL^{-1})	-0.56	0.4	0.1672	-0.34	0.1	0.0022
P(mgL^{-1})	-5.02	11.46	0.6632	0.36	3.18	0.9094
Conductivity(µScm)	0.51	0.33	0.1314	1.13	0.28	0.0002
Transparency (cm)	8.49	1.51	<.0001	-2.09	0.88	0.0221

Production Performance and Survival Rate of Nile tilapia

The analysis of variance showed that location influenced significantly ($p< 0.05$) the growth performance of the fish throughout the study period. The mean final body weight(FnBW), weight gain (WG), daily growth rate (DGR), specific growth rate (SGR), survival rate (SR) and estimated annual yield were significantly higher for the Nile tilapia raised at Mbarali than for those raised at Mufindi (Table 3). Similarly, the mean final body length(FnBL) and final body width(FnBWd) were higher for the fish grown at

Mbarali (body length =21 ± 0.16 cm and width = 7.71 ± 0.07 cm), than for those grown at Mufindi (body length =16.14 ± 0.15 cm and width = 5.55 ± 0.07 cm). Generally, it was clear that fish raised at Mbarali increased in body weight over time at a faster rate compared to those reared at Mufindi district (Fig. 2). The results also showed that fish raised at Mbarali had significantly better feed conversion ratio (FCR) (1.49 ± 0.06) than those raised at Mufindi district (2.16 ± 0.06), (Table 3).

Table 3: Comparison of Growth performance (LSM ± SE) of tilapias grown in ponds located in warm and cold climate (Mbarali and Mufindi districts)

	Locations		
Variables	**Mbarali**	**Mufindi**	p value
InBW (g)	1.16 ± 0.03 [a]	0.83 ± 0.03 [b]	<.0001
FnBW(g)	228.68 ± 4.99 [a]	86.68 ± 4.99 [b]	<.0001
WG (g)	227.70 ± 4.79 [a]	85.71 ± 4.79 [b]	<.0001
DWG(g/d)	1.26 ± 0.03 [a]	0.48 ± 0.03 [b]	<.0001
SGR (%)	3.12 ± 0.02 [a]	2.52 ± 0.02 [b]	<.0001
Yield (kg/ha/year)	6828.43 ± 407.95 [a]	4465.29 ± 407.95 [b]	0.0352
SR (%)	89.47 ± 0.02 [a]	88.02 ± 0.02 [b]	<.0001
InBL (cm)	3.67 ± 0.04 [a]	3.48 ± 0.04 [b]	0.001
FnBL(cm)	21.87 ± 0.16 [a]	16.14 ± 0.16 [b]	<.0001
InBWd(cm)	1.06 ± 0.02 [a]	1.06 ± 0.02 [a]	0.7167
FnBWd(cm)	7.71 ± 0.07 [a]	5.55 ± 0.07 [b]	<.0001
FCR	1.49 ± 0.06 [b]	2.16 ± 0.06 [a]	0.0069

*[ab]= *Means with the same superscript letter in the same row are not significantly different* (p >0.05*).*
InBW = initial body weight, FnBW = final body weight, InBL = Initial body length, FnBL = final body length, InBWd = Initial body width, FnBWd = final body width, WG = weight gain, DWG = Daily weight gain, SGR = specific growth rate, SR = survival rate, FCR = Feed conversion ratio

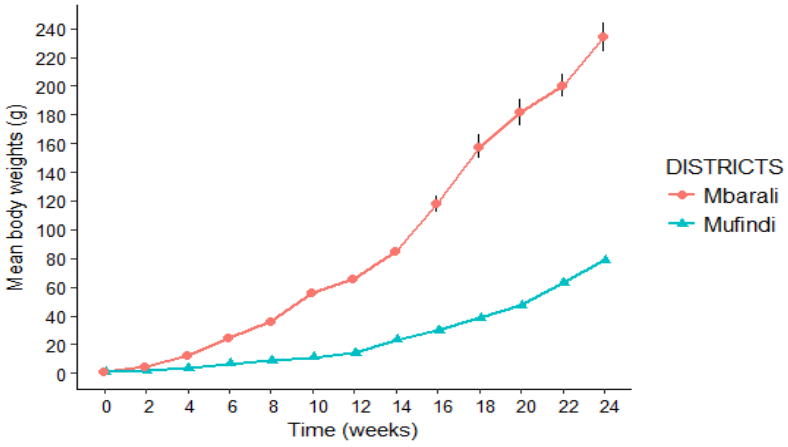


Figure 2: Growth patterns of Nile tilapia raised at Mbarali and Mufindi districts during the experimental period of 24 weeks (six months)

DISCUSSION

Water Quality Parameters

This study was conducted to investigate the growth performance of Nile tilapia grown under two different climate conditions. It was hypothesized that different in climate conditions do not affect growth performance of Nile tilapia. The results in the present studyrevealed significant difference in temperature between the two experimental locations, whereby water temperature was higher in Mbarali than in Mufindi. The relatively higher water temperature corresponded with higher feed intake, SGR and better FCR for the fish grown in Mbarali than for the fish reared in Mufindi where the average temperature was relatively low. These results are supported by the findings of various studies which showed that growth rate increases with increase in temperature within the tolerable range (De Croux *et al*., 2004; Makori *et al*., 2017; Saber *et al*., 2004). Temperatures of between 20 and 35 ℃ have been reported by various authors as being the ideal range for tilapia culture (Ngugi *et al*. 2007). Bhatnagar and Devi (2013) and El-Sherif and El-Feky (2009) recommended temperatures ranging from 25 to 30^0C as

optimum for proper growth and survival of Nile tilapia. Basing on the findings from this study, it appeared that the temperatures at Mufindi were below the ideal range for proper growth of Nile tilapia while the temperatures at Mbarali were within the required range for optimal growth of Nile tilapia.

Slight difference was observed in pH values between the two experimental locations. Nile tilapia can survive in water with pH ranging from 3.5 to 12, but they grow best at a pH ranging from 6 to 9 (Bahnasawy *et al*., 2003; Santhosh and Singh, 2007) while the pH < 4 or >10.5 is lethal (Bhatnagar *et al*., 2004). In this study the average pH value in both locations were in acceptable range and did not differ significantly between the two locations.

Dissolved oxygen, as one of the most important water quality parameters, influences the growth, survival, feed utilization, distribution, behaviour and physiology of Nile tilapia and other aquatic organisms (Bhatnagar and Devi, 2013). In this study, oxygen levels did not differ significantly between the two experimental locations. The mean values were within the acceptable range of 5 to 8 mgL^{-1} which has been recommended by various authors as suitable for optimal growth and production of tilapia (Bhatnagar and Singh, 2010; Bhatnagar *et al*., 2004; Riche and Garling, 2003). However, the growth rate was higher at Mbarali where the mean DO was slightly higher than that of Mufindi. These results are in agreement with the findings by Makori (2017) who observed increased fish growth and yields in ponds with relative higher DO concentration.

Conductivity indicates freshness of water since it is an index of the total ionic content of the water. It influences primary production and thus, fish production (Bhatnagar and Devi, 2013). In this study, conductivity levels varied significantly between the ponds

located in the two experimental locations. The average conductivity obtained at Mbarali was higher and lied within the acceptable range compared to that of Mufindi where the value was very low. Russell *et al*. (2011) suggested the conductivity ranging from 150 to 500 µS/cm while Stone *et al*. (2013) recommended the range of 100 to 2000 µS/cm as ideal for fish pond. Variation in conductivity levels between the two experimental locations could be attributed to factors like soil composition or the bedrock on which the ponds were seated (Russell *et al*., 2011) and nature of human activities around the ponds as noted by Crane (2006). Also the variations could be due to the effect of temperature which influences chemical reactions (Bhatnagar and Devi, 2013). Water temperature affects viscosity, which, in turn, affects ionic activity and conductivity. It has been established that, inverse relationship exists between temperature and viscosity.This means that an increase in temperature will decrease viscosity, which in turn will increase the mobility of ions in water. As such, an increase in temperature increases conductivity (Miller *et al*., 1988; Wetzel, 2001).

Total alkalinity indicates inorganic carbon content of water. Since inorganic carbon is essential for photosynthesis, alkalinity affects primary production and hence, fish yield (Egna and Boyd, 1997). From the present study, alkalinity differed significantly between the two locations. However, the mean values in both locations were within the ideal ranges (50 to 300 mg¯L) for fish growth (Bhatnagar and Devi, 2013; Santhosh and Singh, 2007; Stone and Thomforde, 2004).

Influence of physico-chemical parameters on fish growth performance

Regression coefficient (b) defines the direction and the magnitude of the slope of a regression line. The positive “b” value associated with a particular water quality parameter in each study site implies that, for every increase of one unit of that parameter,

there was a corresponding increase in fish weight by a certain unit. For example, the regression equation predicted significant increase of 3.25 and 9.49 g of fish weight with every increase of one unit of temperature at Mufindi and Mbarali, respectively. This may imply that, increase in temperature was an important factor for the increased growth rate of fish at Mufindi than in Mbarali where temperature was almost at optimal level. Again, the negative 'b' value associated with a particular water quality parameter in each district implies that, for every increase in one unit of a particular parameter there is a decrease of a certain amount of fish weight in that particular district. From this study it is clearly shown that, only ammonia had significant negative influence on the growth of fish in both experimental locations.

Production performance

The growth performance of Nile tilapia is highly influenced by environmental conditions of the pond water. The results from this study show that, sex-reversed Nile tilapia performed better in ponds located at Mbarali (the area with high temperature) than in ponds located at Mufindi (the area with low temperature). Final body weight, weight gain, daily weight gain, specific growth rate and estimated annual yield were significantly higher for fish reared at Mbarali where there was high water temperature than for those reared in Mufindi where there was low water temperature. These results are supported by the findings from previous studies which showed that growth rate increases with increase in temperature within the tolerable range (De Croux *et al*., 2004; Makori *et al*., 2017; Saber *et al*., 2004). Various studies have reported low growth rate and poor feed utilization as temperature goes below 20^0C (El-Sherif and El-Feky, 2009; Khater*et al*., 2017; Popma and Lovshin, 1996). This is due to increased energy cost for maintenance of metabolism, loss of appetite i.e. reduced feed consumption and decrease in feed digestibility and assimilation efficiency since they are temperature dependent through

enzymatic kinetics (Azaza *et al*., 2008). Therefore, high growth performance of fish grown at Mbarali could be attributed to the desirable temperature which was within the accepted range of 25 to 30^0C for proper growth and survival of Nile tilapia (Azaza *et al*., 2008; Bhatnagar and Devi, 2013; El-Sherif and El-Feky, 2009 and Saber *et al*. 2004).

The results for mean SGR obtained at Mbarali are in line with those obtained by Abo-State *et al*. (2009), who reported SGR of between 3.308 and 3.513%/day in tilapia grown at an average temperature of 27.5 ^{0}C. Other water quality parameters that probably contributed to higher growth rate at Mbarali compared to Mufindi include desired levels of water salinity, alkalinity and conductivity which differed significantly between the two locations, with higher values being observed at Mbarali.

Survival rate

The survival rates of Nile tilapia in this experiment differed significantly between the two experimental locations. There was higher survival rate at Mbarali than at Mufindi. The higher survival rate at Mbarali was possibly attributed to better water quality conditions throughout the experimental period, particularly the suitable average water temperature, dissolved oxygen, pH, conductivity and salinity which were in the optimal range for survival of Nile tilapia (Bhatnagar and Devi, 2013; Saber *et al*.,2004). These results are in agreement with El-Sherif and El-Feky, (2009) who reported higher survival rate of Nile tilapia grown at high temperature than in those areas with lower water temperature.

CONCLUSIONS AND RECOMMENDATION

From this study, it is concluded that, climatic conditions of an area influence water quality parameters and hence,fish performance (growth rate, feed utilization efficiency, production yield and survival rate) of Nile tilapia (*Oreochromis niloticus*). Production is

higher for fish grown at Mbarali, where temperature and most of the water quality parameters are relatively better than those of Mufindi district.It is recommended that, further studies be done to determine other fish species that can perform better in an environment with lower temperature. Moreover, further studies should be done on the alteration of feed quality and quantity as well as proper management of water quality parameters also the economics of production should be taken into consideration.

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CHAPTER THREE

MANUSCRIPT II

COMPARISON OF BODY LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR FOR NILE TILAPIA (*Oreochromis niloticus*) CULTURED IN TWO DIFFERENT ECOLOGICAL CONDITIONS IN TANZANIA

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ABSTRACT

This study compared the length-weight relationship and condition factor (K) of sex reversed Nile tilapia (*Oreochromis niloticus*) raised in two districts of Tanzania which experiences different climatic conditions. The districts were Mbarali in Mbeya region where the condition is moderately warm and Mufindi in Iringa region where it is relatively cold. Four ponds located in two different sites were selected from each district. Fish were grown for six months from October 2017 to March 2018. The ponds were fertilized with urea and diammonium phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2, respectively, before stocking and then every two weeks after stocking. Fish were fed daily a diet containing 25% crude protein. Fifty fish were randomly sampled from each pond and measured fortnightly alongside with physic-chemical water quality parameters. The results showed that, the regression coefficient (b) values for the length-weight relationships were 2.87 and 2.94 in Mbarali and Mufindi, respectively. These b values

indicate negative allometric growth of fish from both experimental locations. The mean condition factor (K) values which is an indication of a healthy status and general well-being of the fish was higher ($p \leq 0.05$) for the fish grown in Mbarali (3.168 ± 0.056) than those in Mufindi (2.166 ± 0.056). The correlation coefficients (r) between body weight and length were 0.956 and 0.952 for the fish in Mbarali and Mufindi, respectively, implies strong relationship between weight and length of fish in both experimental locations. Coefficients of determination (r^2) were 0.996 and 0.996 for Mbarali and Mufindi, respectively, indicating that 99% of the variance was explained by the model. It is concluded that there are better environmental conditions for growth, survival and wellbeing of Nile tilapia at Mbarali than Mufindi district.

Keywords: *Allometric growth, Correlation coefficient, Isometric growth, Regression coefficient.*

INTRODUCTION

Growth in many organisms occurs in various patterns. In fishes, both isometric and allometric growth pattern occurs. Isometric growth occurs when an organ grows at the same rate as the rest of the body while allometric growth occurs when an organ grows at a different rate from the rest of the body (Olopade*et al*., 2015; Taylor *et al.*, 2005). When length increases in equal proportion with body weight, the fish is said to exhibit isometric growth. The regression coefficient for isometric growth is usually‘3’ and values greater or less than ‘3’ indicates allometric growth (Getso *et al*., 2017; Olurin and Aderibigbe, 2006). The comprehensive knowledge of growth rate and pattern of fish plays an important role in fishery management. Various biometric relationships are often used to transform data collected in the field into appropriate indexes. One of the common relationships used in analysis of fishery data is Length-weight relationship (Ayoade and Ikulala, 2007). The length-weight relationship (LWR) serves several purposes including estimation of the biomass from known length and for morphometric interspecific and comparative growth studies in fisheries management (Adam and Khalid, 2016; Mendes *et al*., 2004; Muchlisin *et al*., 2017).

The length-weight relationships also provide information for computing condition factor. The condition factor serves as an indicator of fatness and general well-being of the fish. It reflects interaction between biotic and abiotic factors in the physiological conditions of fish in relation to its welfare (Getso *et al.,* 2017;Keyombe, 2017). Condition factor (K) in the lifetime of fish may vary with change in physiologic factors, locations, climatic condition, time and stages of development of fish (Blackweel *et al.,* 2000; Moutopoulos and Stergiou, 2002). Higher value of condition factor reflects better condition experienced by fish (Abdoli and Rasooli, 2008). Therefore, in fisheries science, the condition factor (K) is used to compare the “condition”, i.e., fatness or wellbeing of fish, with the

hypothesis that “heavier fish of a certain length are in a better physiological condition” (Kumolu-Johnson and Ndimele, 2010; Seher and Suleyman, 2012). It is also a useful index for monitoring feeding intensity, age, mortality, life span, growth rates, and reproduction in fish (Kumar *et al.*, 2014; Ujjania *et al.*, 2012).

In Tanzania, Nile tilapia is the most preferred species for aquaculture and it is grown almost all over the country. This is probably due to its good qualities, including ability to survive in diverse environmental conditions, high growth rate, high food utilization efficiency, good fecundity and good flesh quality (Jamil *et al.*, 2004; Neves *et al.*, 2008). A number of environmental factors, such as water temperature, oxygen concentration, pH, salinity, alkalinity and concentrations of suspended solids influence the rate of growth of cultured fish. In Tanzania, different agro-ecological zones in the country have different environmental conditions such as temperature, oxygen concentration, salinity, alkalinity and biological components, which may affect condition factors. However, information on the influence of environmental conditions prevailing in different parts of the country on growth pattern and condition factor of cultured Nile tilapia is scant. Moreover, it is not well known whether the length-weight relationship of tilapia differs in different environmental conditions. The objective of this study was to assess the length-weight relationship and condition factor for sex-reversed Nile tilapia grown in two regions of Tanzania which experience different climatic conditions.

MATERIALS AND METHODS

Experimental location and source of fish

The study was conducted in two districts located in different regions of Tanzania; Mufindi and Mbarali districts in Iringa and Mbeya regions, respectively. Mufindi district lies between latitude $8^0$00'– $9^0$15' S and longitude 34^0 35' –35^0 55' E. The mean annual

rainfall ranges from 950 to1600 mm.Temperatures are often below 15 ^{0}C, the mean monthly is 18.4 ^{0}C (maximum temperature experienced in November and February) and the minimum is 13.1 ^{0}C and it is observed in July. The altitude ranges from 1700 to 2200 meters (m) above sea level (Nuru, 2013). Mbarali is located between latitude 7^0 and 9^0 S and between longitude 33.8^0 and 35^0 E. The altitude ranges from 1000 to 1800 m above sea level. Average temperature ranges between 25 and 30 ^{0}C. The annual rainfall is about 450 to 650 mm (Chenyambuga *et al*., 2014).

Fish species used in the experiment

Fingerlings of sex-reversed male Nile tilapia (*Oreochromis niloticus*) with an average weight of 1.00 g were used in this study. The fingerlings were obtained from Ruvu Fish Farm located at Kibaha district, Coast region, Tanzania.

Pond preparation, stocking and management

In each district, two sites were selected and at each site two ponds were used, making a total of four ponds per district. Before stocking, all ponds were drained, cleaned, dried for seven days and then refilled with water. All ponds were fertilized with urea and Diammonium phosphate (DAP) at rate of 3 g/m^2 and 2 g/m^2, respectively. All ponds were stocked with sex reversed Nile tilapia fingerlings (*Oreochromis niloticus*) at a stocking density of 2 fish/m^2 seven days after initial fertilization. During the experimental period the ponds were fertilized fortnightly with urea and DAP using the same rate indicated above. Fish were fed with a supplementary diet containing 25% Crude protein (CP) twice daily; in the morning starting from 10.00 to 10.30am and in the evening starting from 4.00 to 4.30 pm. The diet comprised of maize bran (50%), fish meal (25%), cotton seed cake (10%), sunflower seed cake (10%), maize meal (4%) and mineral premix (1%). The fish were fed daily at a feeding level of 10% of their body weight during the first month

of the experiment and then the amount was reduced to 5% of body weight from the second month up to the end of the experimental period. The experiment lasted for six months.

Data collection

The first measurements for fish body weight and length were taken after two weeks of acclimatization and these were considered as initial body weight and length. During the experimental period,a random sample of fifty fish was taken from each pond for data collection. Each fish in the sample was measured individually for weight (g) and length (cm). Body weight was measured to the nearest 0.01 g by using a sensitive weighing balance and total body length (cm) was measured to the nearest 0.1 cm using a measuring ruler. The total length of each fish was measured from the tip of the snout to the end of the caudal fin. Subsequent measurements of body weight and length were done at an interval of two weeks up to the end of the experimental period (180 days).

Statistical analysis

The relationship between length and weight of the fish was examined by using correlation analysis and simple linear regression. The coefficient of correlation (r) which represents the degree of association between length and weight was computed using the Statistical Analysis System software (SAS, 2000) for Windows. The parameters of length-weight relationship of the sampled fish were evaluated using the following equations:

$$W = a L^{b}$$

Where; W = weight of fish in grams (g)

L = The total length of fish in centimetres

a = Exponent describing the rate of change of weight with length (= the

intercept of the regression line on the Y-axis)

b = an exponential expressing relationship between length-weight i.e. weight

at unit length (slope of the regression line)

The log transformed relationship ($W = aL^b$) gives the following regression equation:-

Log w = log a + b log L

Where; a = Constant

b = the regression co-efficient (slope of the line)

The logarithmic transformation was done to make the equation W = a Lb (Thomas *et al*., 2003). Linear representation of the graph, which shows the slope and the intercept were also plotted using Excel.

Condition Factor: The condition factor (K) of the experimental fish was estimated using the following formula:

$K = 100\ w/L^b$

Where; W = Weight of the fish (g)

L = the total length of the fish (cm)

b = the value obtained from the length-weight equation formula.

(Adam and Khalid, 2016)

All statistical analyses of the collected data were carried out using the General Linear Model (GLM) of SAS (2000) for Windows. Significant differences were judged at a probability level $p \leq 0.05$.

RESULTS

Length-Weight relationship and condition factor

The weekly mean weights and lengths of fish grown in both experimental locations are shown in Table 1. The final total length of fish reared in Mbarali (warm climate) and Mufindi (cold climate) ranged from 18.85 to 22.30 cm and 15.86 to 15.98 cm,

respectively. Body weights ranged from 131 to 459 g and 76.35 to 81.29 g for fish reared at Mbarali and Mufindi, respectively. It was obvious that fish reared in warm environment (Mbarali) had larger size than those reared in cold environment (Mufindi).

Table 1: Mean weekly fish body weights and lengths (mean ± se)

	Mbarali		Mufindi	
Week	**Body weight (g)**	**Body Length (cm)**	**Body Weight (g)**	**Body Length (cm)**
2	4.65 ± 0.14	5.60 ± 0.06	1.83 ± 0.13	4.35 ± 0.06
4	12.77 ± 0.63	7.80 ± 0.12	3.51 ± 0.61	5.81 ± 0.11
6	24.62 ± 0.80	10.60 ± 0.12	6.72 ± 0.78	7.23 ± 0.12
8	36.49 ± 0.93	12.25 ± 0.12	9.04 ± 0.90	7.55 ± 0.11
10	55.83 ± 1.70	13.72 ± 0.15	11.17 ± 1.66	8.32 ± 0.14
12	65.60 ± 1.89	14.38 ± 0.15	14.08 ± 1.84	9.09 ± 0.15
14	85.24 ± 1.54	15.38 ± 0.16	23.35 ± 1.50	10.51 ± 0.16
16	118.14 ± 3.23	17.44 ± 0.16	29.93 ± 3.14	11.78 ± 0.15
18	157.87 ± 4.13	19.05 ± 0.17	38.33 ± 4.02	12.78 ± 0.17
20	181.77 ± 4.27	20.05 ± 0.17	47.47 ± 4.15	14.07 ± 0.16
22	200.61 ± 4.01	21.22 ± 0.16	62.90 ± 3.91	14.56 ± 0.15
24	234.36 ± 5.18	22.01 ± 0.16	78.62 ± 5.04	15.92 ± 0.16

The correlation coefficients (r) which indicates the degree of relationship between body weight and length of the fish were almost similar for fish grown in Mbarali (r = 0.9558) and those grown at Mufindi district (r = 0.9524). However, both indices indicated strong relationship. The analysis of length-weight relationships of Nile tilapia raised in both districts showed that fish in both districts exhibited allometric growth pattern ($b \neq 3$). The 'b' values in both districts were less than 3 i.e. negative allometric growth pattern and the values differed ($p \leq 0.05$) between the two experimental locations (Table 2). The coefficients of determinations (r^2) were the same in both experimental locations (Figure 1).

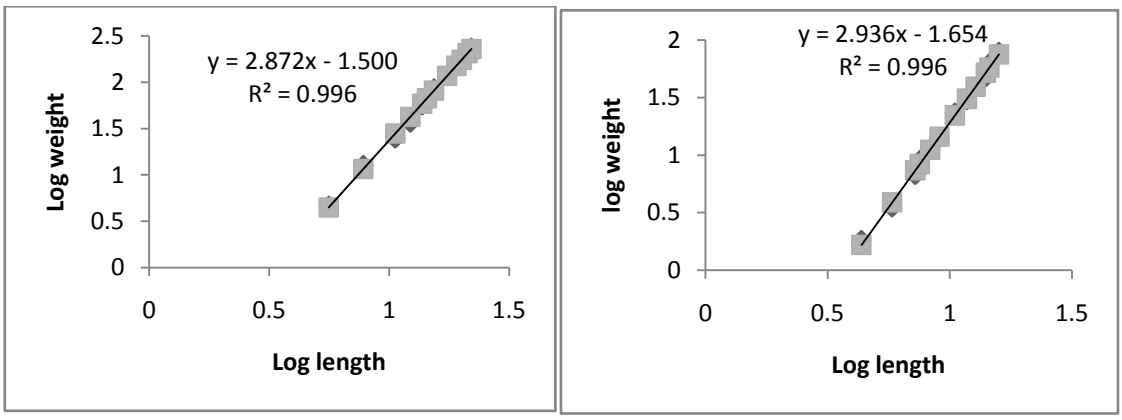
Condition factor (K)

The mean condition factors were not consistent throughout the experimental period (Figure 2). The mean condition factor ranged from 2.74 to 3.50 in Mbarali and 1.96 to 2.40 in Mufindi. The mean values of condition factor (K) were higher ($p \leq 0.05$) for fish grown in Mbarali where there is relatively high temperature than of those grown in Mufindi where the temperature is low (Table 2).

Table 2: Overall Length-Weight relationship and Condition factor of Nile tilapia (*Oreochromis niloticus*) grown from warm (Mbarali district) and cold (Mufindi district) locations

	Locations	
Variables	**Mbarali**	**Mufindi**
r^2	0.9963	0.9961
R	0.9558	0.9524
a	0.22	0.19
b	2.87^{b}	2.94^{a}
K (LSM +SE)	3.168 ± 0.056^{a}	2.166 ± 0.056^{b}

$*^{ab}$*= Means with the same superscript letter in the same row do not differ significantly (*p>*0.05).*
(a and b = regression coefficients; K = condition factor; r^2 = correlation coefficient; R = coefficient of determination)



(a) Mbarali (b) Mufindi

Figure 1: Log length-log weight relationship for Nile tilapia (*Oreochromis niloticus*) reared in Mbarali (a) and Mufindi (b) districts

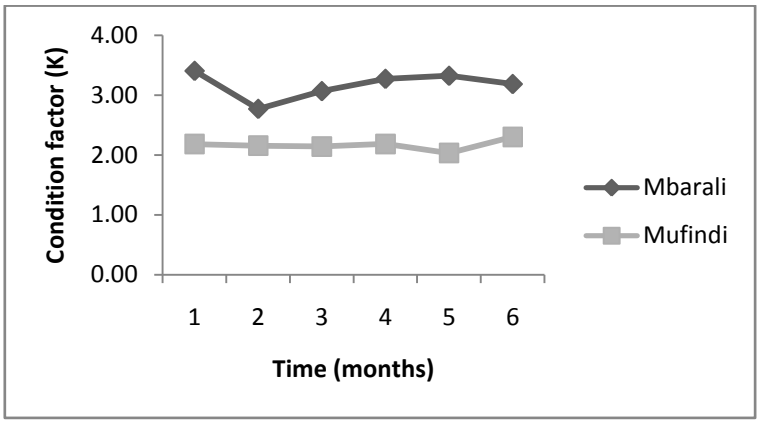


Figure 2: Comparison of condition factor (K) for Nile tilapia reared at Mbarali and Mufindi during the experimental period

DISCUSSION

Length-Weight Relationship

The length-weight relationship (LWR) serves as an important tool that gives information on growth pattern of fish (Ighwela *et al.*, 2011). From the results in the present study, the correlation coefficients of combined data revealed a high degree of relationship between body length and weight of above 95% for fish grown in both experimental locations. These results are in agreement with those of Moradinasab *et al*. (2012) who reported significant increase in weight with increase in length. The coefficients of determination (r^2) was also high,implying that the increase in weight gain of fish were highly related to the increase in body length (Muchlisin *et al*., 2017).

The exponential value of the LWR ‘b’ was significantly higher for fish grown at Mbarali where temperature was high than that of fish reared at Mufindi where it wascold. In both experimental locations, the exponential values ‘b’ obtained were slightly less than ‘3’, indicating negative allometric growth pattern of the fish (Migiro *et al*., 2014). However, in both locations the values were within the range of 2 to 4, recommended as appropriate

for fresh water fishes (Anani and Nunoo, 2016; Golam and Al-Misned, 2013). The variations in the value of the exponent 'b' could be the result of the influence of numerous factors such as seasonal environmental fluctuations, physiological conditions of the fish at the time of data collection (e.g. gonadal development and nutritive conditions of the environment) (Hossain *et al*., 2006; Jennings *et al*., 2001), geographical conditions, fish size, stage of maturation, fullness of the gut and degree of muscular development (Gupta and Banerjee, 2015; Ujjania *et al*., 2012). Muchlisin *et al*. (2010) argued that, the b value can also be affected by fish behaviour, for instance, active swimming fish may show lower b values compared to passive swimming fish, possibly due to energy allocation for movement and growth. Shukor *et al*. (2008) supported this idea and argued that, fast flowing stream environment could lower b value and vice versa.

Condition Factor (K)

Condition factor (K) reflects the physiological state of a fish in relation to its welfare (Anani and Nunoo, 2016). It is frequently used to compare the effects of biotic and abiotic factors on the health or general well-being of a fish population (Dambatta *et al*., 2017; Otieno *et al*., 2014). The K value also gives information when comparing two populations living under certain feeding, density, climate and other conditions (Golam and Al-Misned, 2013).

From the present study, the mean condition factor of sex reversed *Oreochromis niloticus* reared in both experimental environments were greater than one, suggesting good fish health, good level of feeding and proper environmental condition (Ayode, 2011; Ujjania *et al*., 2012). The mean value of condition factor obtained for the fish raised at Mbarali district was significantly higher than that obtained from the fish grown at Mufindi district. This implies that the environmental conditions in Mbarali district were more favourable

for the growth and survival of the fish than those at Mufindi district (Nehemia *et al*., 2012: Olopade *et al*., 2015).

Results from this study also revealed that the fish cultured in the two different study areas exhibited inconsistent condition factors during the experimental period. The monthly variations in condition factors could be attributed to various reasons like changes in environmental factors with time (e.g. water quality), availability of natural food supply, physiological condition e.g. accumulation of fat and gonads development (Jennings *et al*., 2001; Ndiaye, 2015) and stage of maturity (Khallaf *et al*., 2003; Olurin and Aderibigbe, 2006; Rodrigues and Araújo, 2003). It has been shown that the better the environmental conditions (physico-chemical and biological parameters) which are within the tolerable limits for growth of Nile tilapia, the higher the condition factor and vice versa (Keyombe *et al*., 2017; Migiro *et al*., 2014). These findings are consistent with the results of the present study whereby higher condition factor and growth performance of fish were obtained at Mbarali, the area where most of the water quality parameters were within the acceptable range.

CONCLUSIONS AND RECOMENDATION

It is concluded that difference in climatic conditions between the two experimental locations influence significantly the length-weight relationship and condition factor of cultured fish. In both experimental locations, fish showed negative allometric growth pattern and there is strong relationship between body weight and length of fish. Nile tilapia (*Oreochromis niloticus*) grown at Mbarali have better condition andare relatively healthier, compared to those grown at Mufindi. It is recommendedthat further studies be done on other species so as to come up with the better species that can survive well in Mufindi district which has cold environment.

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CHAPTER FOUR

MANUSCRIPT III

COMPARISON OF BIOMASS, SPECIES AND BIOCHEMICAL COMPOSITIONS OF PLANKTON COLLECTED FROM PONDS LOCATED IN TWO DIFFERENT ECOLOGICAL CONDITIONS IN TANZANIA

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ABSTRACT

This study was carried out to determine biomass, biochemical composition and species composition of plankton collected from fish ponds located in two different ecological conditions in Tanzania. The study was conducted in Mbarali district where the climate is moderately warm and Mufindi district where the climate is relatively cold. Assessment of species composition revealed no significant difference between the two experimental locations ($p > 0.05$). Sevenclasses of phytoplankton and five classes of zooplankton were identified. The phytoplankton classes included *Bacillarophyceae*, *Chlorophyceae*, *Chrysophyceae*,*Cynophyceae*, *Euglenoidea*, *Hormogoneae* and *Zygnemaphyceae*. Zooplankton classes included *Eurotatoria*, *Foraminifera*, *Heterotrichea*, *Monogononta* and *Tubulinea*. Significantly higher counts of phytoplankton species were observed from Mbarali compared to those from Mufindi district ($p < 0.05$) while the zooplankton species showed no significant difference between the districts ($p > 0.05$). The ponds in Mbarali had higher ($p<0.05$) algal biomass (51.74 ± 1.83 gDM/m^2) compared to those in Mufindi

(39.25 ± 1.83 gDM/m^2). Crude protein (CP) content of the algae was significantly higher for plankton collected from Mbarali (16.46 ± 0.65%) than of those from Mufindi (14.44 ± 0.65%). No significant differences were observed in dry matter (DM) and ether extract(EE) contents between the algae collected from the two experimental locations, while ash content was significantly higher in algae found in Mufindi (32.77 ± 0.1.00%) than those in Mbarali (26.22 ± 1.00%). The analysis of proximate composition of fish sampled from the experimental ponds revealed significantly higher EE for fish grown in Mbarali than for those grown at Mufindi. Nosignificant differences were observed on DM, CP and ash contents of fish from both experimental locations. Regression analysis revealed positive and significant influence of plankton CP on fish growth. From this study, it is concluded that difference in climatic conditions has no influence on phytoplankton species composition in fish ponds located in Mbarali and Mufindi districts. However, a climatic conditions influenceplankton biomass and species abundance.

Keywords: *Phytoplankton, proximate chemical composition, zooplankton*

INTRODUCTION

Planktons area large and highly diverse group of organisms which are found in almost all earth ecosystems, not just aquatic but also terrestrial. They live in various environments ranging from hot springs to arctic snow and they have various colours, but mostly they occur in green, brown and red colours (Raja *et al*., 2008). Plankton can be subdivided into two groups, eukaryotic and prokaryotic algae, based on the organization of their cells. Examples of prokaryotic plankton are Cyanobacteria (*Cyanophyceae*) and eukaryotic planktons are green algae (*Chlorophyta*) and diatoms (*Bacillariophyta*) (Richmond, 2004). There are about 25,000 species of algae, of which only about 40 species are used in aquaculture (Raja *et al*., 2014). Some species of phytoplankton are harmful and

associated with detrimental effects like low dissolved oxygen and toxicity in aquatic ecosystem (Egerton and Marshall, 2014).

Planktons play important roles in aquaculture. Their main functions relate directly or indirectly to the nutrition impact and their influence on water quality.Generally planktons are considered as important primary food producers in aquatic food chain (Raja *et al*., 2008). Their abundance, biomass and species composition directly affects the nutrition, growth, reproduction and survival of fish in a pond (Nihed, 2017). Planktons can be used directly as food for some fish species or indirectly, as food for zooplankton such as rotifers which are essential source of food for fish (Brown and Robert,2002; Muller-Feuga, 2000; Welladsen *et al*., 2014). Most phytoplankton species have ability to convert light energy and carbon dioxide (CO_2) into biomass (e.g. carbohydrates, proteins and lipids) through photosynthesis process (Karthikeyan, 2012; Murray *et al*., 2013; Park *et al*., 2011).They have fast growth rate and possess simple structure which increases their photosynthetic efficiency, thus providing sustainable feedstock in aquatic ecosystem (Fuentes-Grünewald *et al*., 2012).

Plankton species composition and biomass depend on the environmental factors such as temperature, light and nutrient availability through enzymatic reactions(Reynolds, 2006). The quantity and quality of algal biomass depends on species and strains as well as environmental conditions such as duration and quality of sunlight, temperature, relative humidity, evaporation, precipitation, topography of lands, nutrients, carbon sources and water qualities (Juneja *et al*., 2013; Sun *et al*., 2015). Consequently, growth and development of fish reared in ponds in which feeding is based on these plankton depends on the quality, proportion and availability of the biochemical constituents and digestibility of the algal cells. The biochemical composition of algae varies with species, light,

temperature, and growth stage. Normally, algal nutrient decreases with age as they enter stationary stages of growth. Generally, total lipid and carbohydrate contents increase while protein content decreases with age (Gatenby *et al*., 2003). In the present study, the species composition, biomass and biochemical composition of plankton collected from fish ponds located in two district experiencing different ecological conditions were assessed.

MATERIALS AND METHODS

Experimental location

The study was conducted in two districts located in different regions of Tanzania; namely Mufindi and Mbarali districts found in Iringa and Mbeya regions, respectively. Mufindi district lies between latitude $8^0$00'– $9^0$15'S and longitude 34^0 35'–35^0 55'E. The mean annual rainfall ranges between 950 and 1600 mm. Temperatures are often below 15 ^{0}C, the mean maximum monthly temperature is 18.4 ^{0}C (November and February) and the minimum is 13.1 ^{0}C (July). The altitude ranges from 1700 to 2200 meters (m) above sea level (Nuru, 2013). Mbarali is located between latitude 7^0 and 9^0S and between longitude 33.8^0 and 35^0E. The altitude ranges from 1000 to 1800 m above sea level. Average temperature ranges between 25 ^{0}C and 30 ^{0}C. The annual rainfall is about 450 to 650 mm (Chenyambuga *et al*., 2014).

Pond preparation, Stocking and Management

In each district, four fish ponds were selected for the study. Before stocking, all ponds were drained, cleaned, well dried for seven days and then refilled with water. Before stocking all ponds were fertilized with urea and Diammonium phosphate (DAP) at an application rate of 3 g/m^2 and 2 g/m^2, respectively. After fertilization the ponds were left for seven days without stocking the fish. All ponds were stocked with sex reversed Nile

tilapia fingerlings (*Oreochromis niloticus*) (weighing approximately 1.00 g of body weight) at a stocking density of 2 fish/m^2. Following stocking, the ponds were fertilized with urea and DAP after every two weeks. The fish were fed with supplementary diet containing 25% Crude protein (CP) twice daily, in the morning at 10.00 am and evening at 4.00 pm. The experiment lastedfor six (6) months.

Data collectionand laboratory analysis

Four pieces of phytoplankton nets, each having a size of 50 cm x 50 cm (2500 cm^2) and 20 µm mesh size, were totally submerged in each pond for algae collection. The nets were placed at different positions in each pond and removed at an inetrval of two months. The attached algae were scrubed from the net, decanted and the residues were collected in airtight bottle containers and then put in a cool box containing ice blocks. The samples were transported to a laboratory within 24 hours. In the laboratory the samples were stored at-18^{0}C until analysis. The stored algal samples were thawed and centrifuged at 3000 rpm at room temperature (25 – 30^{0}C) for 10 minutes to concentrate the algal cells and then oven dried at 60^{0}C for 48 hrs. The dried samples were analysed for dry matter (DM), crude protein (CP), Ether extract (EE) and ash contents according to AOAC (2000) method. Crude protein content was calculated using a conversion factor of 6.25 (Agwa *et al*., 2012; Samek *et al*., 2013).

The algal samples used for determination of species composition were collected by taking four mls of scrubed algal sample and placed in 5 ml vials. The samples were preserved by using formalin solution (4% concentration) and stored in the laboratory at room temperature. To determine algae species, 10 µL of the sample in dublicate were taken using pipette and placed in the neubor chamber slide for observation and counting. Observations were done using an inverted microscope with 10X magnification. The

average number observed and counted in each square were multplied by convertion factor (10^4) to get the counts per milliliter. Results for the plankton were expressed as mean number of algae per group.

At the end of experiment, five fish were randomly sampled from each pond and then stored at -18^{o}C in the laboratory. Both fish and algae samples were analysed for biochemical composition using proximate analysis scheme (AOAC, 2000). Fish samples were first prepared following a series of processes including thawing, thorough cleaning, eviscerating and deboning. Flesh samples were then dried at 60^{o}C for 24 hours and then ground to pass in a 2 mm sieve size. Determination of dry matter, ash, crude protein and ether extract were done according to AOAC (2000). Crude protein content was calculated using a conversion factor of 6.25 (Agwa *et al*., 2012).

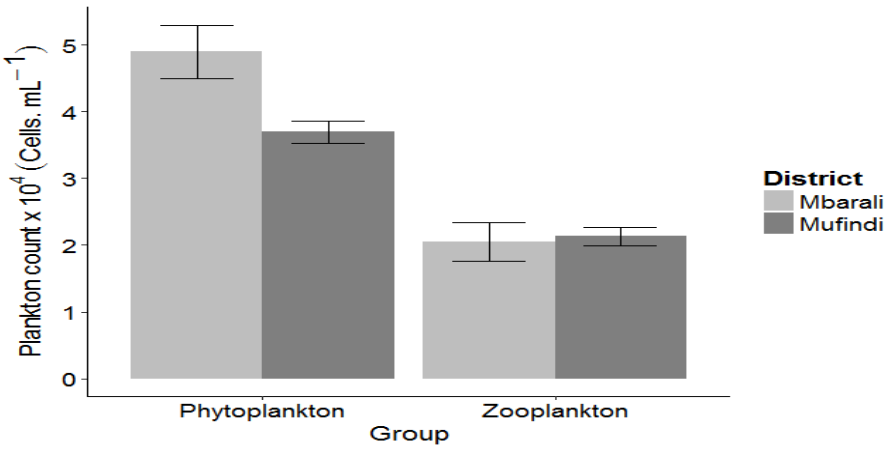
Statistical analysis

Descriptive statistics were computed to get mean and standard error for biomass, number of species and biochemical composition parameters. Analysis of variance (ANOVA) was used to test the effect of location on biomass, species composition and biochemical composition parameters. Duncan's New Multiple Range test was used to test the significance of the differences between a pair of treatment means. The relationships between algal and fish proximate chemical composition parameters were determined using correlation analysis while the influence of algal chemical composition on fish growth and chemical composition were assessed using multiple regression analyses. All statistical analyses were performed using the General Linear Model (GLM) of the Statistical Analysis System software (SAS, 2000) for Windows. Significant differences were judged at a probability level of $p \leq 0.05$. All graphical presentations were plotted using R Studio software version 3.5.0 (Horton and Kleinman, 2015).

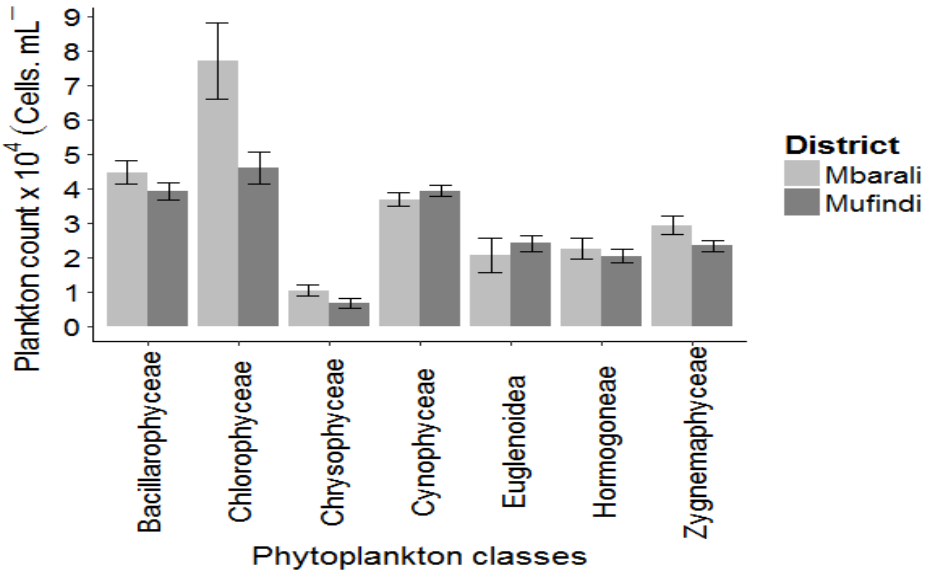
RESULTS

The analysis of variance revealed significantly higher counts of phytoplankton species in Mbarali compared to that of Mufindi district. No significant difference was observed for zooplankton species counts between the two districts (Figure 1). Of the phytoplankton species, significant differences in counts were observed between the species belonging to the following classes;*Chlorophyceae, Chrysophyceae* and *Zygnemaphyceae*. Species belonging to the class *Chlorophyceae, Bacillarophyceae* and *Cynophyceae* had higher counts in both experimental locations. For zooplankton, the species belonging to the class *Monogononta* showed significantly higher countsin Mufindi than in Mbarali. Species belonging to the class *Foraminifera* exhibited the highest counts in both experimental districts. The common genera belonging to the various classes of plankton in both experimental locations are shown in Table 1.

(a)



(b)



(c)

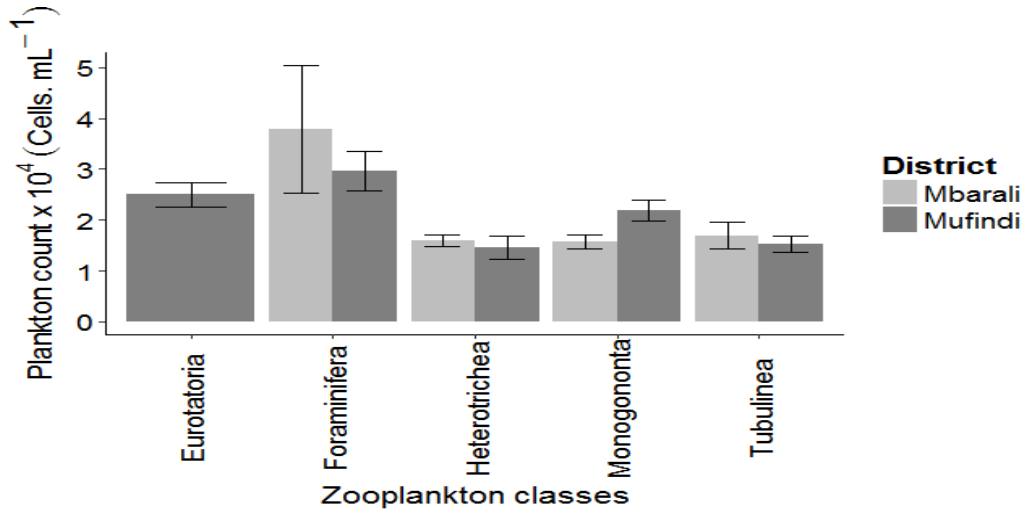


Figure 1: Plankton species composition in ponds located in two districts, Mbarali and Mufindi

Table 1: Species composition (classes and genera) of plankton collected in fish ponds located in two districts, Mbarali and Mufindi

Phytoplankton classes	Plankton genera	Mbarali(counts)	Mufindi (counts)
Bacillarophyceae	*Cocconeis*	38000	46667
	Cymbella	60000	–
	Frustulia	44815	46250
	Gomphonema	46875	36140
	Nitzschia	140000	–
	Synedra	43333	32963
Chlorophyceae	*Chlorococcum*	*196970*	*82469*
	Microspora	*38333*	*28333*
	Monoraphidium	*32105*	*22619*
	Pandorina	*10667*	*16667*
	Scenedesmus	43704	27436
	Stauridium	23000	10000
Chrysophyceae	*Dinobryon*	10476	6667
Cynophyceae	*Aphanizomenon*	45208	40588
	Arthrospira	28571	32500
	Cylindrospermopsis	51852	39667
	Lyngbya	38148	43333
	Microcystis	-	63333
	Oscillatoria	24848	34000
	Planktothrix	33333	43889
Euglenoidea	*Phacus*	20667	24167
Hormogoneae	*Anabaena*	22632	20370
Zygnemaphyceae	*Cosmarium*	29697	23939
	Staurastrum	28889	23030
Zooplankton classes			
Eurotatoria	*Lecane*	-	25000
Foraminifera	*Nodulina*	37778	29744
Heterotrichea	*Spirostomum*	15926	14667
Monogononta	*Keratella*	15714	21875
Tubulinea	*Arcellinida*	14444	18000
	Difflugia	17667	12222

Table 2 shows the results for analysis of biomass and biochemical composition (proximate composition) of the plankton and Nile tilapia grown in ponds located at both experimental locations (Mbarali and Mufindi districts). No significant differences were observed on dry matter (DM) and ether extract (EE) contents between the algae collected from Mbarali and Mufindi districts ($p > 0.05$). There was significant differences in crude protein and ash contents obtained ($p<0.05$). Significantly higher ($p \leq 0.05$) algal biomass (51.74 ± 1.83 g DM/ m^2) was obtained for plankton samples collected from ponds located in Mbarali district than of those collected from ponds located in Mufindi district (39.25 ± 1.83 g DM/ m^2).

Table 2: Comparison of algal and fish (flesh) proximate compositions between Mbarali and Mufindi districts

Variables	Mbarali	Mufindi
	Algal proximate composition	
%DM	94.70 ± 0.23^{a}	94.79 ± 0.23^{a}
%CP	16.46 ± 0.65^{a}	14.44 ± 0.65^{b}
%Ash	26.22 ± 1.00^{b}	32.77 ± 1.00^{a}
%EE	1.63 ± 0.23^{a}	1.30 ± 0.23^{a}
	Fish proximate composition	
%DM	93.15 ± 0.60^{a}	94.29 ± 0.60^{a}
%CP	76.68 ± 0.89^{a}	75.45 ± 0.89^{a}
%Ash	13.90 ± 0.25^{a}	13.66 ± 0.25^{a}
%EE	18.42 ± 0.70^{a}	15.55 ± 0.70^{b}

$*^{ab}$*= Means with the same superscript letter in the same row are not significantly different (*p>*0.05)*:
DM = Dry matter; CP = Crude protein; EE = Ether extract

Similarly, no significant differences ($p > 0.05$) were observed for dry matter (DM), ash and crude protein contents between the Nile tilapia raised in the two districts. However, the crude protein (CP) content ($76.68 \pm 0.89\%$) and ash content ($13.90 \pm 0.25\%$) were

slightly higher in fish raised in Mbarali district than of those raised in Mufindi district. Significantly higher EE ($p \leq 0.05$) were observed for the fish raised in Mbarali than of those grown in Mufindi.

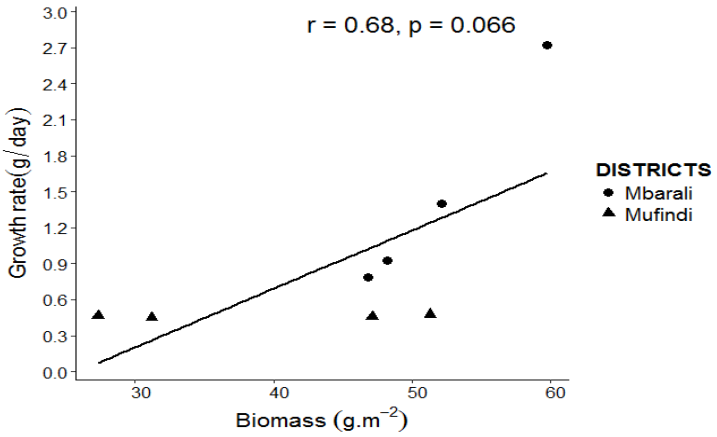
Correlation of plankton proximate composition and fish body (flesh) proximate composition revealed non-significant relationship for all variables in the combined data. A positive correlation was observed between algal DM and fish (DM) and between algal EE and fish EE while CP and ash components showed negative correlation (Table 3). Regression analysis of algal quality on fish growth rate revealed that algal biomass, crude protein and ether extract had positive influence on the growth of fish at Mbarali but not at Mufindi district (Fig. 2). Ash content showed negative correlation with fish growth for both districts.

Table 3: Correlation matrix of plankton and fish proximate compositions (valuesin bold are pvalues)

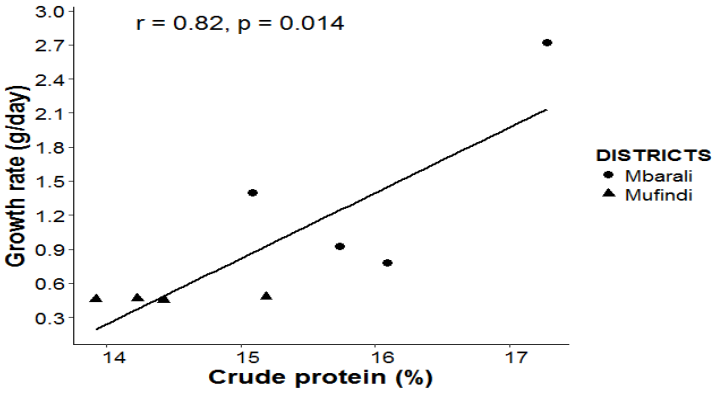
		Algal proximate composition			
	Variables	DM	Ash	CP	EE
Fish proximate composition	DM	0.21633	0.66427	-0.50309	-0.58332
		0.6069	**0.0724**	**0.2038**	**0.129**
	Ash	-0.38587	-0.49618	0.36241	0.18607
		0.3451	**0.2111**	**0.3776**	**0.6591**
	CP	0.33766	-0.21612	0.11159	0.22995
		0.4134	**0.6072**	**0.7925**	**0.5838**
	EE	-0.03816	-0.48151	0.7759	0.12732
		0.9285	**0.227**	**0.0236**	**0.7638**

DM = Dry matter; CP = Crude protein; EE = Ether extract; GR = Growth rate

(a)



(b)



(c)

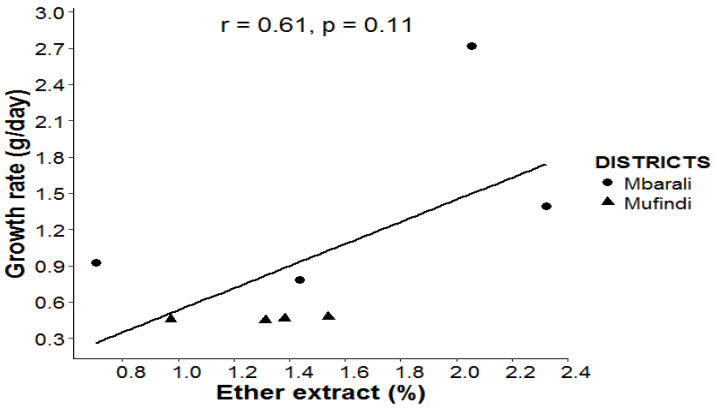


Figure 2: Relationship between Nile tilapia (*Oreochromis niloticus*) growth rate and algal Biomass (a), Crude protein (b) and Ether extract (c)

DISCUSSION

Plankton species composition in fish ponds is influenced by environmental conditions of the locality. In the present study, the analysis of variance indicated no significant difference in plankton species composition between the ponds in Mbarali and Mufindi. However, the results indicated that there is significantly higher mean biomass yield of plankton in ponds located at Mbarali compared to those of Mufindi districts. The higher plankton biomass in Mbarali corresponded with higher final fish body weight, daily weight gain and specific growth rate. The observed higher plankton biomass in Mbarali than in Mufindi could be attributed to differences in environmental conditions between two localities(Santhoshkumar*et al*., 2015). Another contributing factor could possiblybe due to the difference in stage of growth of the plankton at the time of harvesting (Gatenby *et al*. 2003).

In addition to the need for nutrients and light, efficient growth of the plankton species highly depends on optimal temperature conditions which play an important role in photosynthesis and cell division (Kudo *et al*., 2000). The optimal temperature range for efficient growth varies among different species and strains. Temperature ranging between 20 and 30 ℃ has been reported by various as authors to be the optimal temperature range for growth of common strains of plankton(Béchet *et al*., 2017; Kudo *et al*., 2000; Li *et al*., 2011; Ras*et al*., 2013; Sandnes *et al*., 2005). An increase in temperature within the optimal range will have positive effect on photosynthesis and cell division by enhancing enzymatic activities (Ras *et al*. 2013; Santhoshkumar *et al*., 2015). Although each plankton species is characterized by its specific optimal growth temperature, the lethal temperatures for many plankton species have been shown to range from 30 ℃ onwards (Béchet *et al*., 2017; Butterwick *et al*., 2005; Kudo *et al*., 2000). The results obtained in the present study are in consistency with Keys *et al*. (2018) who also reported that the

highest biomass was obtained at higher temperature as it corresponds with maximum photosynthetic rates.

In the present study, the proximate composition results for crude protein and ash contents of plankton from both experimental locations were consistent with the findings obtained by Tortolero *et al.* (2016) who reported the range of 9 to 32% CP and 6 to 42% for ash. The observed higher content of crude protein for plankton collected from Mbarali where the temperature is relative high could possibly be due to variation in abundance of various species, since various species possess different levels of biochemical compositions (Guschina and Harwood, 2006). Also it could be due to the difference in stage of growth (Gatenby *et al*., 2003).Sirakov *et al*. (2015) argued that, different microalgal species can differ significantly in their nutritional value, which may also vary with change in culture conditions. Planktonether extract contents in the present study were very low in both experimental locations. This is contrary to the observation by Selvarajan *et al*. (2015) who reported that, many microalgal strains naturally have high contents of ether extracts (20%–50% of dry weight). Moreover, the results in this study contradict with the findings by Converti *et al*. (2009) who reported significant increase in lipid content of *Chlorella vulgaris* by 2.5 folds as temperature decreased from 30 ℃ to 25 ℃. The same trend was found when Xin *et al*. (2011) studied the temperature effect on lipid accumulation in *Scenedesmus spp*. whereby a decrease in temperature from 25 ℃ to 20 ℃ increased the ether extract content by 1.7 fold.

The results for biochemical composition of the harvested fish shows that, the mean values for DM, CP and Ash contents did not differ significantly between the two locations. Significant difference was observed on EE contents. Fish reared at relatively high temperature (Mbarali) were found to have slightly higher ether extract and protein

contents than those reared in low temperature (Mufindi). This observation supports the findings of the previous studies on body composition of *Oreochromis niloticus* reared at different water temperature (Assem *et al*., 2013; Bahnasawy, *et al*., 2003; Caulton, 1982; Dagne *et al*., 2013; El-Sayed *et al*., 1996). These authors argued that, the low body lipids and protein contents in fish reared in lower water temperature could be due to the fact that, body protein and lipids contents were used to supply energy to the fish reared at lower temperature to meet the increased physiological demands following depletion of energy sources. It is obvious that, as environmental temperature goes lower, the energy demand for maintenance of body temperature increases.

Regression analysis of algal quality and quantity on fish growth revealed that, algal CP had a significant influence on the growth rate of fish, particularly those grown at Mbarali district. Both algal biomass and ether extract had slight influence on fish growth rate at Mbarali but not at Mufindi. This could be attributed, probably, to low temperature at Mufindi which decreased metabolic activities, hence, enzymatic reaction required for digestion of plankton components by fish. This is due to fact that, digestive enzymes (e.g. protease, lipase and amylase) work better at optimal temperature and their activities increases as temperatures increase within the optimal range (Hanna *et al*., 2008; Pang *et al*., 2011; Taylor *et al*., 2005).

CONCLUSION AND RECCOMENDATIONS

From the results of the present study, it has been shown that variation in climatic conditions had no significant influence on plankton species composition. The study has shown that climatic conditions influence plankton biomass and chemical composition, particularly crude protein and their utilization by fish. Furthermore, the study has revealed that fish grown in warn temperature has higher ability to utilize plankton components than

those grown in colder climate. Although the results are promising, it is recommended that furtherresearch to be done on the effect of climatic conditions and other important water quality parameters on the growth and quality of various species of plankton used in aquaculture.

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CHAPTER FIVE

GENERAL DISCUSSION

Growth performance and productivity of Nile tilapia (*Oreochromis niloticus)* is highly influenced by environmental conditions in which they are cultured. The present study aimed at evaluating water quality parameters, production performance, length-weight relationship and condition factor of Nile tilapia (*Oreochromis niloticus)* cultured in two districts of Tanzania; Mbarali where temperature is moderately high and Mufindi where temperature is relatively low. Furthermore, the biomass, species composition and biochemical composition of plankton collected from fish ponds located in these two districts were assessed.

The results show that, fish grown at Mbarali had better growth performance than those grown at Mufindi. Fish grown at Mbarali showed higher feed intake, Daily Growth Rate (DGR), Specific Growth Rate (SGR), Final Body Weight (FnBW), Survival Rate (SR), estimated annual yield and better Feed Conversion Ratio (FCR) than those grown at Mufindi. These results are in line with the findings obtained by Makori *et al*. (2017) and Saber *et al*. (2004) who found that, higher growth rate and final body weights are obtained as water temperatures increase within the tolerable limits. It has been shown that as temperature goes below 20 ^{0}C, growth rate decreases due to increased energy cost for maintenance of metabolism, loss of appetite that result into reduced feed consumption and decrease in feed digestibility and assimilation efficiency through enzymatic kinetics (Azaza *et al*., 2008). Furthermore, digestive enzymes (e.g. protease, lipase and amylase) work better at optimal temperature and their activities increase as temperatures increase within the optimal range (Hanna *et al*., 2008; Pang *et al*., 2011; Taylor *et al*., 2005).

Apart from its effects on fish growth, temperature also influences several other water quality parameters and can alter the physical and chemical properties of water. The relatively higher water temperatures at Mbarali were accompanied with desirable levels of other physico-chemical water quality parameters such as conductivity, alkalinity, salinity, DO, pH together with higher plankton biomass and abundance. The combined effect of all these factors could have been the reason for the better growth, survival and yield of fish grown at Mbarali compared to those grown at Mufindi district.

The exponential value of the length–weight relationship ‘b’ and condition factor (K) were significantly higher for the fish grown at Mbaraliand the ponds had good physico-chemical water quality parameters and higher plankton biomass yield than those at Mufindi district. In both experimental locations, the exponential values (b) of the length–weight relationships obtained were slightly less than ‘3’ indicating that, fish reared in both districts exhibited negative allometric growth pattern (Migiro *et al*., 2014). The mean condition factor of sex reversed Nile tilapiareared in both environmental locations were greater than one, suggesting good fish health, good level of feeding and proper environmental condition (Ayode, 2011; Ujjania *et al*., 2012). However, the higher condition factor value obtained for the fish raised at Mbarali district than that of the fish grown at Mufindi district implies that, the environmental conditions at Mbarali district were more favourable, and thus provided better well-being for the growth and survival of fish than those at Mufindi (Nehemia *et al*., 2012: Olopade *et al*., 2015).

GENERAL CONCLUSION AND RECCOMENDATION

This study evaluated the growth performance, water quality parameters and condition factors (K) of Nile tilapia reared in ponds located in two districts which experience

different climatic conditions, Mbarali where temperature is relative high and Mufindi where temperature is low. From this study, it is concluded that;

i. The difference in climatic conditions influences significantly the water quality parameters of the fish ponds located in the two districts.
ii. The differences in climatic conditions between the two experimental locations significantly influence the growth performance and yield of the fish. Better performance wasobserved for fish grown at Mbarali compared to those grown at Mufindi.
iii. The fish reared in both districts exhibited negative allometric growth pattern. The climatic conditions of Mbarali are more suitable for the growth, survival and wellbeing of Nile tilapia compared to those in Mufindi.
iv. The differences in climatic conditions in the two experimental locations do not significantly influence the plankton species composition; rather it affectsplankton biomass and chemical composition.

It is recommended further studies on the different fish species which can perform better on areas with low temperature conditions be conducted.

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APPENDICES

Appendix 1: Summary of results for water quality parameters at Mufindi district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
Temperature	21.93	44	25.79	18.85	1.86	8.45	3.43	6.94
pH	6.97	44	9.69	5.33	1.001	14.37	1.003	4.36
DO	6.09	44	9.57	3.10	1.49	24.55	2.23	6.47
Salinity	0.01	44	0.02	0.01	0.005	35.74	0.00002	0.01
Conductivity	31.81	44	54.67	17.00	9.16	28.79	83.89	37.67
Transparency	17.25	44	26.00	10.00	3.21	18.58	10.27	16.00
NH4	4.33	44	7.28	2.24	1.25	28.91	1.57	5.04
NO3	7.71	44	11.76	5.60	1.43	18.56	2.05	6.16
Alkalinity	82.39	44	175.00	47.00	25.92	31.47	672.01	.128.00
Pho	0.99	44	4.37	0.20	0.94	95.85	0.89	4.17

Appendix 2: Summary of results for water quality parameters at Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
Temperature	27.72	44	32.40	24.92	2.10	7.56	4.38	7.48
pH	6.91	44	9.43	5.23	1.06	15.26	1.11	4.20
DO	6.17	44	10.31	2.36	2.22	36.05	4.95	7.95
Salinity	0.06	44	0.14	0.03	0.02	40.59	0.001	0.11
Conductivity	121.62	44	237.00	58.00	43.36	35.65	1880.22	179.00
Transparency	15.73	44	32.00	6.00	7.38	46.93	54.48	26.00
NH4-N	4.88	44	8.40	2.52	1.25	25.56	1.56	5.88
NO3 -N	7.72	44	12.32	4.76	1.85	23.96	3.42	7.56
Alkalinity	105.30	44	225.00	62.00	36.45	34.62	1328.72	163.00
Pho	1.33	44	6.03	0.16	1.29	96.81	1.66	5.87

Appendix 3: ANOVA table for temperature

Dependent Variable: Temp

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F=
District	1	738.6886545	738.6886545	259.79	<.0001
Site(District)	2	96.9265545	48.4632773	17.04	<.0001
Error	84	238.842136	2.843359		
Corrected Total	87	1074.457345			

R-Square	Coeff Var	Root MSE	Temp Mean
0.777709	6.793074	1.686226	24.82273

Appendix 4: ANOVA table for pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.06275568	0.06275568	0.06	0.8081
Site (District)	2	2.26652955	1.13326477	1.07	0.3468
Error	84	88.75447727	1.05660092		
Corrected Total	87	91.08376250			

R-Square	Coeff Var	Root MSE	pH Mean
0. 5573	14.80873	1.027911	6.941250

Appendix 5: ANOVA table for DO (mg/L)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.15056364	0.15056364	0.05	0.8284
Site(District)	2	41.04939091	20.52469545	6.44	0.0025
Error	84	267.6193909	3.1859451		
Corrected Total	87	308.8193455			

R-Square	Coeff Var	Root MSE	ppmDO Mean
0.633411	29.13077	1.784922	6.127273

Appendix 6: ANOVA table for Salinity (mgL^{-1})

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.04321023	0.04321023	285.90	<.0001
Site(District)	2	0.01168409	0.00584205	38.65	<.0001
Error	84	0.01269545	0.00015114		
Corrected Total	87	0.06758977			

R-Square	Coeff Var	Root MSE	PSU Mean
0.812169	34.78618	0.012294	0.035341

Appendix 7: ANOVA table for Conductivity (µS/cm)

Source	DF	Squares	Sum of Mean Square	F Value	Pr > F
District	1	177447.4961	177447.4961	376.40	<.0001
Site(District)	2	44855.9264	22427.9632	47.57	<.0001
Error	84	39600.6794	471.4367		
Corrected Total	87	261904.1019			

R-Square	Coeff Var	Root MSE	Conductivity (µS/cm) Mean
0.848797	28.30247	21.71259	76.71625

Appendix 8: ANOVA table for water transparency (cm)

Source	DF	Squares	Sum of Mean Square	F Value	Pr > F
District	1	51.011364	51.011364	3.64	0.0597
Site (District)	2	1608.181818	804.090909	57.42	<.0001
Error	84	1176.295455	14.003517		
Corrected Total	87	2835.488636			

R-Square	Coeff Var	Root MSE	SSC Mean
0.585152	22.69519	3.742127	16.48864

Appendix 9: ANOVA table for Ionized Ammonia(mgL^{-1})

Source	DF	Squares	Sum of Mean Square	F Value	Pr > F
District	1	6.63301818	6.63301818	4.24	0.0425
Site(District)	2	3.15856818	1.57928409	1.01	0.3684
Error	84	131.2760455	1.5628101		
Corrected Total	87	141.0676318			

R-Square	Coeff Var	Root MSE	NH4 Mean
0.69411	27.13505	1.250124	4.607045

Appendix 10: ANOVA table for Nitrogen nitrate(mgL^{-1})

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.00589091	0.00589091	0.00	0.9629
Site (District)	2	8.36198182	4.18099091	1.55	0.2186
Error	84	226.8444545	2.7005292		
Corrected Total	87	235.2123273			

R-Square	Coeff Var	Root MSE	NO3 Mean
0. 557600	21.30295	1.643329	7.714091

Appendix 11: ANOVA table for Total alkalinity ($mgCaCO_3^-L$)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	11546.18182	11546.18182	14.36	0.0003
Site(District)	2	18507.50000	9253.75000	11.51	<.0001
Error	84	67524.17091	803.85918		
Corrected Total	87	97577.85273			

R-Square	Coeff Var	Root MSE	Alkalinity Mean
0. 799307	30.21327	28.35241	93.84091

Appendix 12: ANOVA table for Phosphorus (mgL^{-1})

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	2.65316364	2.65316364	2.17	0.1444
Site (District)	2	6.87318182	3.43659091	2.81	0.0657
Error	84	102.6473636	1.2219924		
Corrected Total	87	112.1737091			

R-Square	Coeff Var	Root MSE	Pho Mean
0. 849205	95.55846	1.105438	1.156818

Appendix 13: Summary of results for growth performance of the fish grown at Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
InBW (g)	1.12	190	4.68	0.170	0.93	83.21	0.871	4.51
FnBW(g)	234.36	190	637.00	61.94	137.16	58.53	18812.06	575.06
WG (g)	233.23	190	632.32	61.70	136.47	58.51	18625.36	570.62
LG	18.39	190	29.00	11.30	3.33	18.11	11.09	17.70
WdG	6.72	190	10.40	3.60	1.48	22.02	2.19	6.80
DWG (g/d)	1.30	190	3.51	0.34	0.76	58.50	0.57	3.17
SGR (%)	3.07	190	3.74	2.26	0.31	10.04	0.10	1.48
SR (%)	87.95	190	89.16	86.50	1.10	1.25	1.21	2.66
InBL (cm)	3.62	190	6.00	2.00	1.05	28.85	1.09	4.00
FnBL(cm)	22.01	190	35.00	13.90	3.98	18.08	15.84	21.10
InBWd(cm)	1.04	190	1.90	0.50	0.359	33.77	0.12	1.40
FnBWd(cm)	7.77	190	12.30	4.70	1.69	21.71	2.84	7.60

Appendix 14: Summary of results for growth performance of the fish grown at Mufindi district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
InBW (g)	0.83	200	2.06	0.22	0.38	46.01	0.15	1.84
InBL (cm)	3.48	200	4.80	2.30	0.55	15.86	0.30	2.50
InBWd(cm)	1.06	200	2.80	0.60	0.22	20.27	0.05	2.20
FnBW(g)	78.62	200	151.36	28.88	25.99	33.06	675.34	122.48
FnBL(cm)	15.92	200	19.80	11.60	1.75	10.97	3.05	8.20
FnBWd(cm)	5.46	200	7.60	3.80	0.75	13.78	0.57	3.80
WG (g)	77.78	200	150.26	28.16	25.92	33.33	672.09	122.10
LG (cm)	12.44	200	16.20	7.40	1.79	14.36	3.19	8.80
WdG (cm)	4.39	200	6.40	2.30	0.76	17.38	0.58	4.10
DWG (g/d)	0.43	200	0.83	0.16	0.14	33.33	0.02	0.67
SGR (%)	2.56	200	3.31	1.76	0.3	12.40	0.10	1.55
SR (%)	89.48	200	89.81	89.02	0.31	0.34	0.09	0.79

Appendix 15: ANOVA table for Final Body Weight (FnBW) (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	1743148.428	1743148.428	398.06	<.0001
Sites(District)	2	321945.119	160972.559	36.76	<.0001
InW	1	273468.255	273468.255	62.45	<.0001
Error	385	1685938.544	4379.061		
Corrected Total	389	6053132.067			

R-Square	Coeff Var	Root MSE	FnW Mean
0.721477	42.83431	66.17448	154.4894

Appendix 16: ANOVA table for Final Body Length (FnBL(cm))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	2834.270979	2834.270979	628.50	<.0001
Sites(District)	2	357.020967	178.510484	39.58	<.0001
InW	1	211.394314	211.394314	46.88	<.0001
Error	385	1736.197541	4.509604		
Corrected Total	389	7217.458077			

R-Square	Coeff Var	Root MSE	FnL Mean
0.759445	11.24275	2.123583	18.88846

Appendix 17: ANOVA table for Final Body Width (FnBWd (cm))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	438.3019450	438.3019450	511.72	<.0001
Sites(District)	2	54.6519644	27.3259822	31.90	<.0001
InW	1	13.2847238	13.2847238	15.51	<.0001
Error	385	329.762565	0.856526		
Corrected Total	389	1059.406769			

R-Square	Coeff Var	Root MSE	FnWid Mean
0.688729	16.73808	0.925487	5.529231

Appendix 18: ANOVA table for Weight Gain (WG(g))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	1743148.428	1743148.428	398.06	<.0001
Sites (District)	2	321945.119	160972.559	36.76	<.0001
InW	1	264056.425	264056.425	60.30	<.0001
Error	385	1685938.544	4379.061		
Corrected Total	389	6008486.213			

R-Square	Coeff Var	Root MSE	WG Mean
0.719407	43.10620	66.17448	153.5150

Appendix 19: ANOVA table for Daily Weight Gain DWG(g/d)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	53.81374569	53.81374569	398.33	<.0001
Sites(District)	2	9.95607470	4.97803735	36.85	<.0001
InW	1	8.12065335	8.12065335	60.11	<.0001
Error	385	52.0129895	0.1350987		
Corrected Total	389	185.3694536			

R-Square	Coeff Var	Root MSE	DWG Mean
0.719409	43.10037	0.367558	0.852795

Appendix 20: ANOVA table for Specific Growth Rate (SGR (%))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	31.35096073	31.35096073	613.38	<.0001
Sites(District)	2	2.12378579	1.06189290	20.78	<.0001
InW	1	6.77414287	6.77414287	132.53	<.0001
Error	385	19.67818402	0.05111217		
Corrected Total	389	64.15670359			

R-Square	Coeff Var	Root MSE	SGR Mean
0.693279	8.051870	0.226080	2.807795

Appendix 21: ANOVA table for Survival Rate (SR(%))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	182.3206821	182.3206821	2712.38	<.0001
Sites(District)	2	104.7932924	52.3966462	779.50	<.0001
InW	1	0.5082897	0.5082897	7.56	0.0062
Error	385	25.8789325	0.0672180		
Corrected Total	389	476.1966667			

R-Square	Coeff Var	Root MSE	SR Mean
0.945655	0.292184	0.259264	88.73333

Appendix 22: ANOVA table for Initial Body Weight (InBW (g))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	10.3336724	10.3336724	48.40	<.0001
Sites(District)	2	111.5902312	55.7951156	261.35	<.0001
Error	386	82.4048999	0.2134842		
Corrected Total	389	202.0398259			

R-Square	Coeff Var	Root MSE	InW Mean
0.592135	47.41651	0.462044	0.974436

Appendix 23: ANOVA table for Initia Body Length (InBL (cm))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	3.4980688	3.4980688	11.64	0.0007
Sites (District)	2	151.2604813	75.6302406	251.61	<.0001
Error	386	116.0250556	0.3005830		
Corrected Total	389	269.3550000			

R-Square	Coeff Var	Root MSE	InL Mean
0.569249	15.44379	0.548255	3.550000

Appendix 24: ANOVA table for fish yield

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
DISTRICT	1	936.250417	936.250417	22.73	0.0001
SITE(DISTRICT)	2	1410.210833	705.105417	17.12	<.0001
Error	20	823.828333	41.191417		
Corrected Total	23	3170.289583			

R-Square	Coeff Var	Root MSE	YIELD Mean
0.740141	14.10690	6.418054	45.49583

Appendix 25: ANOVA table for Feed Conversion Ratio (FCR)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.22317243	0.22317243	9.22	0.0560
Site(District)	2	3.53880447	1.76940223	73.10	0.0029
InW	1	0.00573854	0.00573854	0.24	0.6597
Error	3	0.07261146	0.02420382		
Corrected Total	7	4.28738750			

R-Square	Coeff Var	Root MSE	FCR Mean
0.983064	6.574782	0.155576	2.366250

Appendix 26: Summary output for analysis of Length-Weight relationship for shish grown at Mufindi

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.998051947							
R Square	0.996107689							
Adjusted R Square	0.995718457							
Standard Error	0.033298126							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	2.837515827	2.837516	2559.167	2.20214E-13			
Residual	10	0.011087652	0.001109					
Total	11	2.848603479						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1.654816075	0.057548805	-28.755	6.03E-11	-1.7830428	-1.526589	-1.7830428	-1.52658935
Log length	2.936193366	0.058041055	50.58821	2.2E-13	2.806869836	3.0655169	2.806869836	3.065516896
a = EXP(-1.65482)	0.191127205							
RESIDUAL OUTPUT								
Observation	*Predicted log weight*	*Residuals*						
1	0.220644492	0.042482432						
2	0.589391697	-0.044257838						
3	0.868309101	-0.041263084						
4	0.922583627	0.033757718						
5	1.046307387	0.001776889						
6	1.159502397	-0.010870441						
7	1.344807042	0.023566321						
8	1.489786407	-0.013682592						
9	1.593723393	-0.010202703						
10	1.716752119	-0.040367197						
11	1.760757132	0.037906632						
12	1.874361222	0.021153864						

Appendix 27: Summary output for analysis of Length-Weight relationship for shish grown at Mbarali

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.998154778							
R Square	0.99631296							
Adjusted R Square	0.995944256							
Standard Error	0.033408049							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*ignificance F*			
Regression	1	3.015923	3.015923	2702.203	1.6794E-13			
Residual	10	0.011161	0.001116					
Total	11	3.027084						
	Coefficients	*ndard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1.500597658	0.063943	-23.4678	4.47E-10	-1.6430712	-1.358124	-1.64307116	-1.3581242
Log length	2.872297605	0.055255	51.98272	1.68E-13	2.74918211	2.9954131	2.74918211	2.9954131
a=EXP(-1.5006)	0.222996844							
RESIDUAL OUTPUT								
Observation	*Predicted Log weight*	*Residuals*						
1	0.647482755	0.019626						
2	1.061847701	0.044375						
3	1.443952284	-0.05269						
4	1.624531412	-0.06236						
5	1.765886818	-0.01903						
6	1.824647778	-0.00773						
7	1.908523418	0.022141						
8	2.065267431	0.007118						
9	2.175469296	0.02282						
10	2.239560579	0.019952						
11	2.310488343	-0.00814						
12	2.355955811	0.013919						

Appendix 28: Summary of results for Length-Weight relation parameters and condition factor for the fish grown at Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
K	3.168	12	3.500	2.738	0.226	7.133	0.051	0.762
a	0.223	12	0.223	0.223	0	0	0	0
b	2.872	12	2.872	2.872	0	0	0	0
R	0.996	12	0.996	0.996	0	0	0	0

Appendix 29: Summary of results for Length-Weight relation parameters and condition factor for the fish grown at Mufindi district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
K	2.166	12	2.403	1.960	0.158	7.309	0.025	0.443
a	0.191	12	0.191	0.191	0	0	0	0
b	2.947	12	2.947	2.947	0	0	0	0
R	0.996	12	0.996	0.996	0	0	0	0

Appendix 30: ANOVA table for Condition Factor (K)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	50.65066952	50.65066952	11.00	0.0009
Sites(District)	2	20.47884736	10.23942368	2.22	0.1083
Error	5066	23326.45691	4.60451		
Corrected Total	5069	23397.34248			

R-Square	Coeff Var	Root MSE	K Mean
0.003030	112.8507	2.145813	1.901462

Appendix 31: Summary of results for proximate composition and yield of plankton collected from Mufindi district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
DM	94.793	24	96.870	92.440	1.088	1.148	1.184	4.430
Ash	32.765	24	43.590	24.960	4.750	14.498	22.565	18.630
CP	14.437	24	15.790	12.510	1.007	6.975	1.014	3.280
EE	1.293	24	1.790	0.130	0.363	28.053	0.132	1.660
YIELD	39.250	12	58.300	24.100	11.841	30.168	140.208	34.200

Appendix 32: Summary of results for proximate composition and yield of plankton collected from Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
DM	94.696	24	96.540	92.800	1.131	1.194	1.279	3.740
Ash	26.216	24	33.060	20.090	3.306	12.609	10.928	12.970
CP	16.049	24	22.400	11.280	3.178	19.800	10.097	11.120
EE	1.458	24	2.110	0.720	0.451	30.950	0.204	1.390
YIELD	51.742	12	62.700	34.100	7.930	15.326	62.886	28.600

Appendix 33: ANOVA table for algal DM

Source	Df	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.11310208	0.11310208	0.09	0.7661
Site(District)	2	1.10973750	0.55486875	0.44	0.6470
Error	44	55.52775833	1.26199451		
Corrected Total	47	56.75059792			

R-Square	Coeff Var	Root MSE	DM Mean
0.021548	1.185696	1.123385	94.74479

Appendix 34: ANOVA table for algal Ash

Source	Df	Sum of Squares	Mean Square	F Value	Pr > F
District	1	514.6990083	514.6990083	39.39	<.0001
Site(District)	2	195.3822417	97.6911208	7.48	0.0016
Error	44	574.959717	13.067266		
Corrected Total	47	1285.040967			

R-Square	Coeff Var	Root MSE	Ash Mean
0.552575	12.25760	3.614867	29.49083

Appendix 35: ANOVA table for algal CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	31.16963333	31.16963333	5.38	0.0250
Site(District)	2	0.73000833	0.36500417	0.06	0.9390
Error	44	254.8223500	5.7914170		
Corrected Total	47	286.7219917			

R-Square	Coeff Var	Root MSE	CP Mean
0.111256	15.78790	2.406536	15.24292

Appendix 36: ANOVA table for algal EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
DISTRICT	1	0.32670000	0.32670000	2.34	0.1329
SITE(DISTRICT)	2	1.58308333	0.79154167	5.68	0.0064
Error	44	6.13018333	0.13932235		
Corrected Total	47	8.03996667			

R-Square	Coeff Var	Root MSE	EE Mean
0.237536	27.12967	0.373259	1.375833

Appendix 37: Summary of results for proximate composition of fish grown at Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
DM	93.153	4	94.930	91.730	1.415	1.518	2.001	3.200
Ash	13.903	4	14.230	13.170	0.501	3.602	0.251	1.060
CP	76.675	4	78.330	74.460	1.951	2.545	3.807	3.870
EE	18.418	4	19.950	16.950	1.517	8.236	2.301	3.000

Appendix 38: Summary of results for proximate composition of fish grown at Mbarali district

Variable	Mean	N	Maximum	Minimum	Std Dev	Coeff of Variation	Variance	Range
DM	94.285	4	96.110	93.090	1.359	1.441	1.847	3.020
Ash	13.663	4	14.240	12.980	0.519	3.797	0.270	1.260
CP	75.448	4	76.430	73.880	1.110	1.472	1.233	2.550
EE	15.545	4	17.190	14.520	1.225	7.879	1.500	2.670

Appendix 39: ANOVA table for fish

Dry Matter (DM)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	2.56511250	2.56511250	1.80	0.2507
Site (District)	2	5.84712500	2.92356250	2.05	0.2435
Error	4	5.69565000	1.42391250		
Corrected Total	7	14.10788750			

R-Square	Coeff Var	Root MSE	DM Mean
0.596279	1.273254	1.193278	93.71875

Appendix 40: ANOVA table for fish

Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	0.11520000	0.11520000	0.45	0.5408
Site(District)	2	0.52625000	0.26312500	1.02	0.4390
Error	4	1.03330000	0.25832500		
Corrected Total	7	1.67475000			

R-Square	Coeff Var	Root MSE	Ash Mean
0.383012	3.687697	0.508257	13.78250

Appendix 41: ANOVA table for fish Crude Protein (CP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	3.01351250	3.01351250	0.96	0.3824
Site(District)	2	2.57862500	1.28931250	0.41	0.6880
Error	4	12.54075000	3.13518750		
Corrected Total	7	18.13288750			

R-Square	Coeff Var	Root MSE	CP Mean
0.308398	2.327921	1.770646	76.06125

Appendix 42: ANOVA table for fish Ether Extract (EE)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
District	1	16.50251250	16.50251250	8.32	0.0449
Site(District)	2	3.46382500	1.73191250	0.87	0.4847
Error	4	7.93855000	1.98463750		
Corrected Total	7	27.90488750			

R-Square	Coeff Var	Root MSE	EE Mean
0.715514	8.296042	1.408772	16.98125