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DEPARTMENT OF FISHERIES AND WATERSHED MANAGEMENT

ASSESSMENT OF ALTERNATIVE INDIGENOUS FISH SPECIES FOR CULTURE IN GHANA; CASE STUDY ON *CHRYSICHTHYS NIGRODIGITATUS* (Lacepède, 1803)

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ASSESSMENT OF ALTERNATIVE INDIGENOUS FISH SPECIES FOR CULTURE IN GHANA; CASE STUDY OF *Chrysichthys nigrodigitatus* (Lacepède, 1803)

By

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DECLARATION

I hereby declare that this work submitted is my own towards the MPhil and, to the best of my knowledge, it contains no previously published material by other persons nor material earlier accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

This study consisted of two parts with the first assessing fish farmers' knowledge on *Chrysichthys nigrodigitatus* in the Ashanti Region while the second aspect assessed the growth performance, feed utilization and body composition of *C. nigrodigitatus* on formulated diets. Aspects of the life history traits, ecology and natural distribution of *C. nigodigitatus* were investigated through a survey on indigenous knowledge on the species. Five farmers in Kumasi and its environs were selected and interviewed to gather information on the species. Overall knowledge on the species was low, farmers indicated that *C. nigrodigitatus* is dominant in the Offin River. The species is omnivorous, survives under pond conditions, feed on compound feeds with appreciable growth of 0.5-1 kg in 6 months. There is the need to protect the species because of their restricted distribution. An experiment was conducted over 10 weeks to determine the optimal inclusion level of protein in diets for *C. nigrodigitatus*, in twelve indoor 60-L rectangular glass tanks designed as flow through systems. Four experimental diets were formulated to be isoenergetic containing varying crude protein (CP) levels (32.1%, 34.6%, 42.8%, and 47.1%) using fish meal/soybean meal as sources of protein. Each dietary treatment was run in triplicate with 12 fingerlings (initial weight 16.30 ± 0.07 g) in a completely randomized design. Results showed that body weight gain (BWG%) and specific growth rate increased up to 42.8% ($P < 0.05$) but declined at 47.1% CP. Protein efficiency ratio followed a similar trend with no significant differences between the treatments. Feed conversion ratio (FCR) decreased with increasing dietary protein level. Dose-response analysis in addition to the polynomial broken stick regression ascertained that the optimal protein requirement in diets for juvenile *C. nigrodigitatus* is 42.8%. Data from proximate composition of fish flesh showed that *C. nigrodigitatus* had CP (15.77%- 19.37%), lipid (2.8%-5%), moisture (73.26%-73.69%) and ash (3.8%-4.96%). It is recommended that diets for juvenile *C. nigroditatus* are formulated with a protein inclusion level of 42.8%.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

Fish, often considered the lowest-cost animal protein is the most merchandised food in the world with a majority of the world trade of fish coming from developing countries. World Bank (2006) indicated that the gap in the supply of food fish in the world is growing having an uneven influence on the poor in their health and nutrition.

However, according to Tidwell and Allan (2001), the sea's sustainable yields are unable to satisfy the growing population demands specifically in poorer countries. According to FAO (2006), the growing demand in the various regions of the world for aquatic food can be managed by the great potential of aquaculture making significant contributions. World Bank (2006) reports that about 15% of the fish consumed globally is accounted for by aquaculture products and a possible future contribution to more than half of food fish supplies in the world since a growing fraction of trade of food in the world is already influenced by aquaculture. This statement is confirmed in the report on World Aquaculture (2010) that aquaculture contributes to the overall capture production and continued growth in 2006 (34.5%) to 2008 (36.9 %) contributing 45.6% of food fish produced globally for humans.

Aquaculture continues to grow as an essential food production (FAO, 2010). Fish culture is considered a more assured approach to increase local fish production especially in developing African countries including Ghana, where the need for fish continues to grow.

Ghana covers approximately 238,500 km^2 and is inundated by river systems. The rivers, lagoons, estuaries and lakes offer diverse habitats for fish (Dankwa *et al*, 1999). The freshwaters have rich aquatic biodiversity, having a greater number of species endemic to definitive catchments. Fishing on most of these water bodies have initially been minimal, due to smaller numbers of fishermen, ineffective traditional fishing gears, less sophisticated fishing crafts and smaller markets. Fish yields have reduced steadily over the years with the increase in human population and corresponding increase in fishing effort. This poses a threat to the biodiversity of these waters especially endemic species. There is a need to employ sustainable methods in conserving the biodiversity of these water bodies while at the same time meeting the needs of local communities who depend on these water bodies for food fish. Aquaculture can be an avenue for improving stocks of commercially important species and also for producing fish for consumption (Davis and Shawl, 2005).

Production of aquatic organisms in Ghana started in traditional systems which included brush parks in lagoons and reservoirs ('atidjas'), fish holes ('hatsis'), miniature dams in coastal lagoons('whedos') and the culture of fresh water clams (*Galatea paradoxa*) in the Lower Volta. However, recent methods used in aquaculture were introduced first in 1950's by the Department of Fisheries with the construction of ponds on experimental levels, reservoirs were stocked with farmed fish and private sector participation was encouraged in the 80's through nationwide campaigns by the government (FAO, 2005-2016).

The aquaculture industry in Ghana is skewed towards the culture of Tilapia

(*Oreochromis niloticus*) and some two species from the catfish family (*Clarias sp* and *Heterobranchus sp*). Although there are a number of suitable species, one economically important genus of fish to mention is *Chrysichthys* (Nwadiaro and Okorie, 1985). *Chrysichthys sp.* is a highly valued fish which is found in a number of the rivers in Africa. (Agnese, 1991; Akinsanya *et al*, 2007; Offem *et al*, 2008; Pangni *et al*, 2008**a**). With reference to Ghana, it forms a large portion of catches from most freshwater bodies especially the Volta Lake at Yeji, Akuse and the Afram plains. This is emphasized by Adjei (2002), who stated that the genus is one of the commonest species in the Volta system. It was also reported that *Chrysichthys sp.* is considered a delicacy for consumers due to the quality of meat. Quarcoopome and Amenvenku (2006) reported that species belonging to the genus *Chrysichthys* together with some Cichlids dominated the commercial fishery in their study of the Fish Fauna of the Weija Resevoir.

Chrysichthys like all other catfishes generally has a remarkable growth rate. Dankwa *et al* (1999) described five (5) species belonging to the genus *Chrysichthys* in the freshwaters of Ghana. These include *C. walkeri, C. auratus, C. johnelsi, C. maurus, and C. nigrodigitatus. C. nigrodigitatus* is characterized by a hardy nature and tolerant to different ecological conditions which has facilitated its culture in the Ivory Coast (Pangni *et al*, 2008b)

1.1 Justification:

There is the need to culture fish to provide protein for the rapidly increasing populations in developing countries makes it a necessity to expand studies on the ecology, biology and management of African freshwater fishes. In Ghana,

Chrysichthys is a high value fish that forms a high percentage of the catch of fishermen and well desired on fish markets. The species have been listed as important food fish which should be considered for culture according to Dankwa *et al* (1999). Being a comparatively new species to aquaculture, knowledge about its ecology and biology especially its dietary requirements is still inadequate with most of the available information restricted to researches in Nigeria and Ivory Coast. References can be made to the work of Nwadiaro and Okorie (1985); Agnese (1991); Akinsanya *et a*l (2007); Offem *et al* (2008) and Pangni *et al* (2008).

A wide range of methods are used in capturing *C. nigrodigitatus* for the market. Methods include gill nets, seines, basket traps, hook and line, bamboo and basket traps with the latter being predominant along the Volta River. The use of bamboo and traps especially raises concerns with the population status of the species over time. *C. nigrodigitatus* is known to feed and breed in holes and crevices are easily caught in holes made in bamboo traps and baskets placed close to or at the bottom of water bodies. The disadvantages here, like with most traditional gears stem from the fact that they are constructed without consideration to filter fish that has not yet been recruited into the stock that can be fished. The result of this is having young immature juveniles killed thereby depleting the stock (Etcheri and Lebo, 1983). In order to evade more destruction to fish stocks occurring naturally, approximately every rise in consumption by humans should be satisfied through aquaculture because producing fish through aquaculture is able to lessen pressure on the overexploited stocks in the wild (Diana, 2009). The IUCN (2010) lists *C. nigrodigitatus* as of least concern under the Red List Category and Criteria, however, in the suggestions for conservation action, it is stated that no information is available and indicated that there is the need for additional studies on the population numbers of the species, the range, ecology and biology, state of its habitat and threats, and also measures for conservation and monitoring.

Information on optimal level of protein in diets is essential to aid in developing sustainable farming which has economic and ecological benefits. However, works done on *C. nigrodigitatus* are still divided and incoherent.

Profitability of aquaculture depends on maximizing the production capability which can only be done with certified information. The need to study the ecology, biology and sustainable management of *Chrysichthys* is therefore significant.

The goal of this study is to ascertain the suitability of *Chrysichthys nigrodigitatus* as a species for culture in Ghana.

1.2 Specific objectives are to

i. Develop a profile of the life history traits, ecology and distribution of *C. nigrodigitatus* based on indigenous knowledge ii. Investigate the effect of varying dietary protein levels on the growth performance and feed utilization of *C. nigrodigitatus* iii. Determine the apparent digestibility of the diets fed to *C. nigrodigitatus* iv. Determine the body composition of *C. nigrodigitatus* fed diets with varying protein levels

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Aquaculture

Aquaculture is the cultivation of organisms (such as mollusks, fish, aquatic plants and crustaceans) in aquatic environments under controlled conditions (Diana, 2009; FAO, 2010). FAO, 2010 states that aquaculture was primarily an Asian activity which has now spread to all continents. The report went on to explain the primary focus of this activity as freshwater cyprinids which has now expanded to encompass the entire aquatic environment and many aquatic species. Exceptional progress in the production of Aquaculture in the last decade has given it improved its prominence in the modern food supply.

According to FAO (2006), aquaculture, currently accounting for close to 50% of food fish produced in the world is doubtless the food-producing sector that is growing fastest perceiving the sector to have the utmost prospective to cater for the rising demand for aquatic food. This statement is further confirmed in Diana, (2009) that with an annual increase of about 9% since 1985, the aquaculture industry is one system of producing food with the fastest growth globally. Aquaculture compared to agriculture converts land to ponds for aquatic crop production and also the use of cages mounted on natural and artificial water bodies e.g. lakes and resevoirs. Fish is an important protein source and has influenced the rapid growth in aquaculture over the years (Offem *et al*, 2009). In the expression of Ofori (2000), aquaculture is considered a way to provides alternatives to fix the decline in fish availability due to stagnation or decline in production from capture fisheries given the increase in population growth. Hecht (2005) explains that aquaculture provides prospects to meet this swelling demand for world's aquatic food resources.

2.1.1 World Aquaculture

Aquaculture in the world has immensely grown over the period of 50 years from producing less than a million tonnes earlier in 1950s to 59.4 million tonnes by 2004 (FAO, 2006). Though the bulk of production (over 75% of all aquaculture harvest) is reported in Asia, aquaculture is known to have grown on all the continents between 1980 and 2000 (Diana, 2009). This production yielded US$ 70.3 billion with 69.6% (41.3 million tonnes) production recorded from China and other countries in AsiaPacific region contributing 21.9%. Contribution from Western European region amounted to 2.1 million tones valued at US$ 5.4 billion (3.5%), whereas 250 000 tonnes (0.4%) is recorded from countries in Central and Eastern
Europe. Correspondingly Latin America and the Caribbean and North America added 2.3% and 1.3%. In 2004 countries near East and North Africa and Sub-Saharan African countries produced 0.9% and 0.2% separately toward the total production globally. The aquaculture sector presently adds about 40 million tonnes to the world's production of aquatic food. According to Hecht (2005), current estimates aimed at retaining the level presently consumed per capita at the lowest, by 2050 global production from aquaculture ought to get to 80 million tonnes. Diana (2009) states predictions of Delgado *et al* (2003) that worldwide production from aquaculture will rise continuously though annual rates will be lesser than 8.8% by 2025.

2.1.2 Aquaculture in Africa

In Africa, fish is the most low-cost and easily available source of animal protein for most people living around water bodies (Olarinmoye *et al*, 2007). Diana (2009), states that developing countries contributed 92.3% to all harvests from culture. According to Hecht (2005) in 2003, the overall production in aquaculture worldwide equaled about 54 786 000 tonnes, of which 0.97% (531 000 tonnes) was contribution from the whole of Africa with 0.13% from Sub-Saharan Africa to the world total production and 13.6% to production of aquaculture in Africa. Aquaculture in Africa was introduced over 50 years ago with most African countries practicing some form of this discipline although at very low rate with Nigeria producing the highest quantities (17 700 mt).
Madagascar follows with 5 100 mt then Zambia contributing 4 700 mt.

According to Machena and Moehl (2001), the main commercial producers of finfish cultured in fresh or brackish water are Nigeria, South Africa, Kenya, Zimbabwe and Côte d'Ivoire. This statement is further confirmed by Hecht, (2005) stating that, aquaculture was made known generally in the 1950s accompanied by governments setting up fish farm stations with objectives highlighting on social issues that included improving nutrition in rural areas, diversifying activities to lessen dangers to crops failure, generation of additional income and creating employment. In Africa, production in aquaculture is basically rural (Machena and Moehl, 2001; Hecht, 2005) with the most major developments appear to have been achieved in Anglophone countries, necessitating increased efforts at capacity building in francophone countries. In the work of Hecht (2005), production of aquaculture from sub-Saharan
Africa is predicted to total between 208 600 and 380 400 tonnes per annum by 2013.

However, aquaculture methods and practices are increasingly transforming recently in many countries in the region with the annualized growth rate through the most recent 15 years being chiefly 30.2% because production from Egypt had surged greatly.

2.1.3 Aquaculture Development in Ghana

Fish supplies 60% of animal protein in Ghanaian diets and about 75% of local consumption of fish produced domestically making fish an essential food product in the country (Cobbina, 2010; Rurangwa *et al*, 2015). According to Rurangwa *et al* (2015), per capita consumption of fish and fishery products in Ghana is projected to stand close to 25 kg per annum. This value being one of the highest recorded in subSaharan Africa. In Ghana, the fisheries sector accounts for 3-5 % to Gross Domestic Product (GDP) which may seem low but its implications especially with provision of employment for a large number of people cannot be over-emphasized. This sector considerably plays a vital role in the economy (Hiheglo, 2008; FASDEP, 2002). Studies over the years have recorded that the demand for fish is far greater than supplied and presently imported fish constitutes 25% of fish consumed locally
(Rurangwa *et al*, 2015).

What is more, capture fisheries is not sufficient to make up for the surplus in demand. Developing aquaculture by the Ghana government therefore is imperative as one of the ways to match demands of fish with quantities supplied and have surplus to export (Hiheglo, 2008). Manu (2004) explains that the anticipation for Ghana will be to adequately supply fish to the population which is continuously growing preferring fish as the chief animal protein source through Aquaculture and culture-based fisheries.

Two different approaches have been founded to historically describe how modern aquaculture was introduced and developed in Ghana. First approach is dated back to the 1950's when fish farming was started in the Northern parts of the country (Cobbina, 2010; Kassam, 2014). Agbo (2008) reports that the then Department of Fisheries began constructing experimental ponds and stocking reservoirs with the fish which were farmed.

A second approach was adopted in the early 1980s and is understood to be the time the private sector began to show real interest in fish farming. The only beneficiaries here were individuals or groups of people who were permitted to make management decisions including landowners. The government launched a nationwide campaign to encourage pond fish culture. The main goal of the government at the time was to encourage culture-based fisheries in freshwater environments considering the prospective benefits of aquaculture which had been underutilized over the years. This campaign was effective since ponds sprung up in different parts of Ghana built by a rather great number of people, particularly in the south of the country. The programme was however not sustainable though the aquaculture industry experienced a substantial number of people participating (Hiheglo, 2008; Cobbina, 2010).

Small scale subsistence farmers practicing extensive system of farming make up the bulk of the sub sector with very few farmers in commercial operations. In the most recent five years there have been five successful commercial operators with two being women (FAO, 2005-2016). Ofori (2002) records up to 2000 farmers with fish ponds (350 ha. total area) yielding averagely 1.0 to 1.5.t ha^{-1} of fish per annum. The contribution of the sub sector to the economy of the nation is not clearly documented separately from the total contribution fisheries makes to the, so the importance of it is not entirely acknowledged. According to Cobbina (2010), the actual contribution of aquaculture to food security, employment and poverty alleviation is not documented.

There are a number of observed challenges perceived in the aquaculture sector. Rurangwa *et al*, (2015) makes a list of factors recognized as being the leading constraints to aquaculture development which include relatively cheaper fish feed not being easily accessible, quality and quantity of seed (broodstock), lack of financial resources for bringing about profitability of aquaculture operations, inadequate involvement of private sector in the development of the aquaculture industry, weak human resource base reflected in the lack of appropriate skills or trained persons at the different levels of the aquaculture sector, nonexistence of effective extension systems for transferring technology, deficiency of national research agenda to respond aquaculture sector needs.

The aquaculture sector in Ghana has prospects of growing (Rurangwa *et al*, 2015). There seem to be a yearly growth in the number of Ghanaians interested in venturing into fish farming. Due to this, the Government of Ghana over the years is fostering collaborations with a number of development partners and institutions in-country in initiating some programmes, regulations and policies that will aid promotion and development of the industry. To obtain increases in aquaculture production, there is a need to reinforce the capacities of existing farmers and encourage new entrants by government knowing how important aquaculture is to growth in GDP and food security. Efforts at developing aquaculture for both short and long term purposes will have to be categorized into two phases. Strengthening institutions directly linked or indirectly to aquaculture in general and culture-based fisheries belong to the first phase.

The next phase ought to be directed towards overcoming the bottlenecks in production identified without compromising the first phase. According to Hiheglo (2008), adding to this, those institutions involved in aquaculture must be resourced properly financially and with staff having the ability to carry out duties efficiently.

Cobbina (2010) clearly indicates that Ghana is gifted with land and water (rivers, lakes and the sea), natural resources endowment capable of supporting aquaculture production.

2.1.4 Aquaculture for conservation

Contamination of surrounding water bodies by mine effluents, industrial discharges and domestic effluent have degraded aquatic ecosystems especially in most of the industrialized world resulting in altered fish populations, and in some cases complete loss of fish (Dankwa *et al*, 2005). According to Olarinmoye *et al* (2007), there are a number of stressors that regularly affect fish which include lack of oxygen, temperatures that are not favorable, high rates in flow of water, unavailability of food and several contaminants caused by activities by humans and from industry. Diana (2009) indicates that satisfying close to all rises in quantities of fish consumed by humans through production from aquaculture will contribute to avoiding extra damages fish stocks occurring naturally. The same author goes on to explain pressure on overexploited wild stocks can be reduced through aquaculture production of fish. This statement is in agreement with the assertion by Anders (1998) that Aquaculture has been used with varying degrees of success to conserve endangered populations. It is possible to enhance stocks that are depleted having limited success with reproduction through stocking organisms (Diana, 2009). Aquaculture is a necessary interim measure to maintain the viability of endangered populations.

Conservation aquaculture explained by Anders (1998) involves use of aquaculture in conserving and recovering threatened populations of fish and this does not in any way has the same risks related natural risks that occur when the wild, native fish populations can no longer be sustained by nature.

2.2 Culture Species

The commercial or recreational culture of finfish, shellfish, and aquatic plants are for food, bait, stocking, research, bioassay tests, markets for ornamental fishes, and as instructional aides. According to Buttner *et al* (1992), species successfully cultured in one place may be unfeasible or unbeneficial in a different place. No one species is applicable in all conditions. In Ghana, several species are commonly cultured by small-scale farmers. Some of these include *Oreochromis niloticus* and other cichlids like, *Sarotherodon galilaeus, Tilapia zillii*, *Heterotis niloticus* and *Hemichromis fasciatus* and catfishes (*Clarias gariepinus* and *Heterobranchus bidorsalis*). Although the tilapias have been identified as the most occurring species, there are no stated figures on the relative importance. FAO (2005-2016) states that in 2004 tilapia moved up to the eighth most popular seafood in the USA global production of all species of tilapia is projected to increase from 1.5 million tonnes in 2003 to 2.5 million tonnes by 2010, with a sales value of more than USD 5 billion. Most of this enhanced production is expected to be attributed to Nile tilapia (*O. niloticus*). The other highly valued indigenous fin-fish species such as *Chrysichthys sp, Gymnarchus niloticus, Mugil sp.* etc. which have high aquaculture potential are largely under-utilized in aquaculture (Erondu, 1997).

Table 2.1Fish species cultured presently and potential future candidates in Ghana

Species	Common names	Remarks
Oreochromis niloticus	Nile tilapia	Main culture species
Tilapia zillii	Red belly tilapia	Cultured by small-scale farmers
Sarotherodon galilaeus	Mango tilapia	“
Sarotherodon	-	“
Melanotheron	Black chin tilapia	‘’
Hemichromis fasciatus	-	Often cultured in poly-culture with tilapia
Clarias gariepinus	North African catfish	
Heterobranchus longifilis	Mudfish	“
Chrysichthys walkeri	Chrysichthys	“
Heterotis niloticus	Africa bony-tongue	“
Parachanna obscura	Snake-head	“
Lates niloticus	African pike	Being considered for aquaculture
Mugil sp.	Mullet	“

Source: (Agbo, 2008)

2.2.1 Tilapia

Tilapia was one of the first fish successfully cultured when aquaculture was introduced in the African continent about 50 years ago and has seen a growth in production of about 58% (Machena and Moehl, 2001). They are the most cultured species on the African continent (Hecht, 2005). FAO (2006) list China as the largest producer of farmed Nile tilapia.

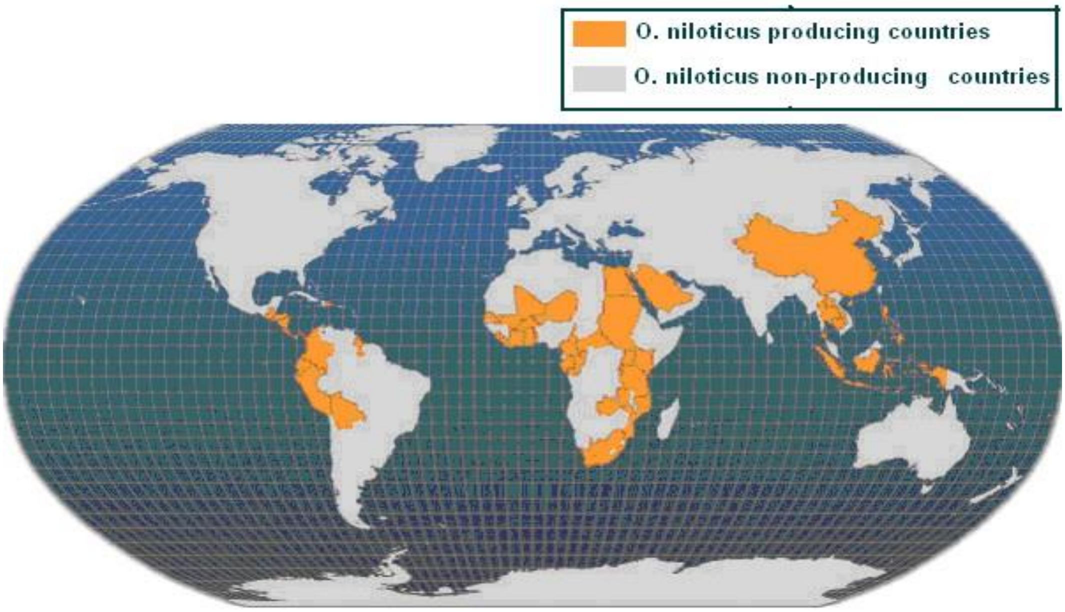

Figure 2.1 Main producer countries of *Oreochromis niloticus* (FAO Fishery Statistics, 2006)

2.2.2 Catfish

Catfishes generally grow at remarkable rates. Due to the capacity to adapt to conditions in ponds, fast rate of growth, acceptance of artificial feeds, ability to tolerate crowding conditions, and high flesh quality (Idoniboye-Obu and Omuaru, 1996). With reference to the African Continent, Catfish has seen the greatest growth in production at 64% (Machena and Moehl, 2001). Catfish is generally significant in the Ashanti Region where a rising domestic demand for catfish is confirmed. Rurangwa *et al* (2015) refers to confirmed increasing domestic demand for catfish to imply that the species is mainly important in the Ashanti Region.

2.3 Alternative Indigenous species

With the teeming increase in human population, a major challenge exists to improve livelihoods of poverty stricken areas and to be able to feed the large populations. With the decline in production from capture fisheries due mostly to anthropogenic factors, there is a corresponding increase in the prices of target fish on the markets and the value of the capture fishery can further be increased when aquaculture thrives (Diana, 2009). Aquaculture is relatively a new industry with significant potential for innovation (Diana, 2009). The search and consideration of new species continues, mostly looking at developing high value indigenous species. Production of these can be targeted at promoting continuing enhancement or restocking in the future to improve livelihoods for individuals relying mostly on fisheries for their livelihoods. The use of indigenous species clearly reduces the risks of disease occurrence and provides more stable production in aquaculture. With concerns and awareness of biodiversity matters growing, the use of indigenous species is eminent with seed production to continue to back programmes that enhance stock in inland waters. Selection of species for farmers is being influenced by the needs of consumers as fish consumption is growing in many countries.

List of indigenous fish species include *Gymnachus niloticus* (Erondu, 1997), *Parachana sp*, *Heterotis sp* and *Chrysichthys sp.*

Plate 2.1 *Chrysichthys nigrodigitatus* (Photographed by Ethel D-T Tettey)

2.4 *Chrysichthys*

There is no doubt of the importance of members of the genus *Chrysichthys* (Lacepède, 1803) in capture fisheries due to its high demand on the markets in most West African countries including Ghana. They are food fish of high economic value and are amongst fishes abundant in commercial catches (Offem *et al*, 2009). Darboe (2002) records *C. maurus* and *C. nigrodigitaus* as some of the most abundant fish species in the Gambian Estuary and confirmed by Albaret *et al* (2004). Ofori-Danson (2002) in his work on the post-impoundment fish stocks on the Yeji section of the Volta lake in Ghana reports that the dominance of Tilapiine species in gillnet catches had given way to claroteids (*Chrysichthys nigrodigitatus* and *Chrysichthtys auratus*). Dankwa and Gordon (2002) also list *Chrysichthys nigrodigitatus* together with five (5) other fish species as being most widely spread in their study of the fish and fisheries found in the Mangrove Swamps of Lower Volta in Ghana. Nonetheless in recent times, there is the attraction for research into their potential in terms of Aquaculture (Fafioye and Oluajo, 2005). Oyelese (2006a) advocates for a further research into and subjecting to suitable possible culture of *Chrysichthys sp*. In Oyelese (2006b**)** there is the stress for the culture of *Chrysichthys* together with *Synodontis sp* and *Chana sp* to be promoted under well monitored conditions. This is imperative since according to Machena and Moehl, (2001), significant concentration of commercial culture of *Chrysichthys* has been recorded in Côte d'Ivoire.

2.4.1 Distribution and Economic Importance

The genus *Chrysichthys* are widely distributed in freshwaters of tropical Africa of which more than 40 species have been described although there are problems in their taxonomy and systematics (Nwadiaro and Okorie, 1985). *Chrysichthys praecox* a new species is described from Lac Mai-Ndombe (Democratic Republic of the Congo) by Hardman and Stiassny (2008). Nwadiaro and Okorie (1985) identified *C. filamentosus* and *C. nigrodigitatus* found in the Oguta Lake in Nigeria. Fafioye and Oluajo (2005) also recorded the presence of *C. walker* and *C. nigrodigitatus* from Epe Lagoon in Nigeria. Nuñez Rodriguez *et al* (1995) with a more specific reference to West Africa categorically stated that the species is one significant species in the region economically. According to Teugels and Thys (1992), the longitudinal distribution of *C. nigrodigitatus*, which is a fresh water classified species, stretches from lower to near upper regions of rivers in West Africa.

The occurrence of *Chrysichthys* species in the water bodies in Ghana is highlighted by IUCN (2010). Dankwa *et al* (1999) describing the distribution of species belonging to this genus listed the occurrence in the Volta, Bia, Tano and Offin basins with especially *C. nigrodigitatus* occurring in all the basins.

Chrysichthys like other catfishes is on high demand on the markets of most African countries (Fafioye and Oluoja, 2005) and are highly valued fish (Offem *et al*, 2008). Oyelese (2006a**)** recorded a proximate protein composition of 50% for *C. nigrodigitatus* flesh which was only slightly lower than 62% and 53.38 in *Clarias gariepinus* species and *Synodontis clarias* respectively but higher than *Chana obscura* (47.36%) and *Tilapia niloticus* (39.61%). He further recorded that *C. nigrodigitatus* had the highest Productive Potential Fish Yield Factor (PPFYF) amongst five fresh water fishes which included *Tilapia niloticus, Synodontis clarias, Clarias gareipinus, and Chana Obscura*. The value of 0.9695 was to translate the quantity of edible flesh to a consumer of a particular species of fish. To Obasohan *et al* (2006), one relished food many people have is *C. nigrodigitatus*. Adjei (2002) acknowledges that *Chrysichthys sp*. is considered a delicacy in Ghana especially with Ashanti Region consumers due to the quality of meat.

Figure 2.2 Distribution of Chrysichthys nigrodigitatus (IUCN, 2010)

2.4.2 Taxonomy

Forty (40) species of the genus *Chrysichthys* have been described although there are problems in their taxonomy and tystematics (Nwadiaro and Okorie, 1985). The number of species stated is in line with the records of Jayabam (1955) who placed *Chrysichthys* as one of the African genera of the Bagrid Family. The work however expressed the need for a complete revision of the genera. References were made to the continuous and discontinuous nature of the vomero-pterygoid dentition as a diagnostic value. Also the occipital region of the head being covered or uncovered with skin and the length-width ratio of the premaxillary band of teeth also appear to be of

Taxonomic value.

Table 2.[1] Family tree" of *Chrysichthys nigrodigitatus*

Phylum	Chordata	Notochord group of animals
Subphylum	Vertebrate	Animals with a backbone
Class	Osteichthyes	Bony fishes
Order	siluriformes	Catfishes
Family	Claroteidae (Tuegels,1995)	Claroteids
Genus	*Chrysichthys*	
Species	*nigrodigitatus*	

Adapted from Dankwa *et al,* (1999)

2.4.3 Biology/Ecology

Knowledge on the biology of *Chrysichthys nigrodigitatus* is imperative for managing and sustainably utilizing stock (Offem *et al*, 2008a).

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[1] **.4.3.1 Meristic features of *C. nigrodigitatus***

Dorsal fin has one spine and nine fin rays, 14 anal fin rays with one spine, 19 caudal fin rays, 7 pectorial fin rays with one spine, and 4 ventral fin rays with one spine (FAPOHUNDA *et al*, 2007). For a diagnostic description, *C. nigrodigitatus* has its post-cleithral process well developed (Hardman, 2008) also slightly notched premaxlllary tooth, bifurcated caudal fin with unequal lobes (Erondu, 1997). *Chrysichthys nigrodigitatus* is a demersal, potamodromous species. The fish occurs in the shallow sections of lakes (less than 4 m), swamps, atop muddy areas and fine sandy bottoms and in rivers (Ezenwa, 1978). In his work, Oyelese (2006a) quoted

Ezenwa (I978) that *C. nigrodigitatus* thrives on soft muddy grounds usually at the mouth of mangrove belts where roots and tangles of plants exist.

2.4.4 Reproduction

Chrysichthys is known to breed seasonally and usually spawn during the rainy season (Oyelese, 2006a). In their work, Nwadiaro and Okorie, (1985) stated that the spawning period of *C. filamentosus* in the Oguta Lake in Nigeria. This was confirmed by Laleye *et al* (1995) that *C. nigrodigitatus* reproduces usually in the rainy and flooding seasons in Ivory Coast. Pangni *et al*, (2008b) stated that current studies indicate that *C nigrodigitatus* spawn for the first time at 2-3 years. Reproduction in *Chrysichthys nigrodigitatus* is a yearly with the spawning season occurring between September and November and 4 months of vitellogenesis, nonetheless spawning and oocyte maturation does not occur without the use of spawning receptacles in cages owing to how the species behave during spawning as explained by Nuñez Rodriguez *et al* (1995).

However, Offem *et al* (2008) specified that C. *nigrodigitatus* has long spawning period, extending from April to August which indicates April-August is the appropriate period to obtain gravid fishes for captive breeding programs. This is contrary to the findings of Erondu (1997), was asserted that *Chrysichthys* like *Gymnarcus* and *Mugil* species cannot be hatchery-bred and since they are not known to reproduce naturally in captivity (i.e., ponds) procurement of the seed is still restricted to collections from the wild. Attempts can therefore be made to artificially breed of the species by providing spawning receptacles as was done in the work of Pangni *et al* (2008a) with artificial PVC nest to facilitate spawning. *C. nigrodigitatus* adjusts better to yearly differences in environmental conditions which possibly activate spawning and vitellogenesis concurrently with other behavioural and pheromonal indications (Nuñez Rodriguez *et al*, 1995). Spawning rate and absolute fecundity according to Pangni *et al* (2008a**),** increases with the age of females of *C. nigrodigitatus*, relative fecundity on the hand decrease with the increase in age of females. It was further stated that the hatching rate and larvae production also is dependent on the fish age. According to Offem *et al* (2008), male *Chrysichthys* species reach maturity at 11.5 cm and females at 16.7 cm total length.

2.4.5 Water Quality Requirements

Growth of fishes cannot be separated from the effects of physico-chemical characteristics of their aquatic habitat (Francis *et al,* 2007). It is undeniably critical to maintain optimum water quality in fish production. Durborow (2000) points to the fact that poor quality of water leads to a surge in numbers of organisms with diseases reducing the capacity of resistance to infection in fish.

Water temperature is known to impact on live functions of fish even in the tropics (Darboe, 2002). Temperature is an essential abiotic factor in the aquatic ecosystem influencing fish activities such as breathing, growth and reproduction and it relates inversely with dissolved oxygen (DO), implying decreases with high temperatures and the other way round (Francis *et al*, 2007).

Oxygen is amongst the essential factors affecting the survival and distribution of fish (Darboe, 2002). According to Francis *et al* (2007) dissolved oxygen (DO) is essential in the aquatic system to fundamental metabolic activities which are vital to the survival of fish. Minimum DO of 4 ppm is acceptable for Catfishes. Counteractive actions applied when concentrations of oxygen fall under 4 to 5ppm is helpful, and it is always best to start aeration in advance to DO concentrations dropping to 4 ppm. Durborow (2000), states that the total oxygen dissolved in water decreases with increases in temperature. The probability of low DO increases with higher fish densities and more food added to the pond.

The chemical relationship between hydrogen (H+) and hydroxyl (OH-) ions is known as pH which is also the measure of the acidity or alkalinity in a constituent. The danger points for fish are pinned at pH 4 and pH 11 which are the acid and alkaline points. These are known as the pH death points. pH of about 6.5-9.0 is accepted as the optimum range for catfish culture. The pH of water in ponds is constantly changing, runs a cycle for 24 hours and this is dependent on several factors. Fish have been observed to eat less and have a less efficient conversion of feed to flesh at pH of 5 or lower and 10 or higher.

Ammonia is found in two forms in water as un-ionized and ionized. With regards to toxicity, un-ionized ammonia (NH_3) is known to be lethal to fish though the ionized ammonia (NH_4+) is non-toxic to fish. Concentration of NH_3 is influenced by pH and temperature. NH_3 increases with increases in pH and same with increase in temperature. A water body is said to be polluted when 1 ppm is recorded as the Total Ammonia Nitrogen, and concerns rise when levels are between 2-3 ppm. Sources of ammonia in water include,

- Inflowing water, particularly run-off from a livestock farmyards

- Animal and plant metabolic excretions. Fish feed is the main supply of ammonia into ponds. About 2.2 pounds of ammonia are let out into the pond for every 100 pounds of catfish feed fed
- Decaying plants and animals
- Uneaten feed

The toxicity of un-ionized ammonia is in two forms:

Acute – in this state, there is deficiency in metabolism of brain energy.

Chronic – The gills in this situation are damaged affecting oxygen intake, salt balance is affected, and other organs equally damaged increasing fish susceptibility to disease. Some ways of correcting ammonia problems: Lower the pH - (usually not economically feasible). One way is the gradual reduction of the ammonia concentrations with lower feed rates. Another approach is to make available a diluted area for fish to go while solutions are figured out by flushing the pond. It is important to make sure there is adequate oxygen throughout the period when the ammonia concentrations are high.

Nitrite (NO_2) causes brown blood disease. Nitrites are tied up with the part of the blood carrying oxygen (hemoglobin) when taken in by fish across gill membranes. This forms a compound known as methemoglobin turning the blood brown and highly unable to transport oxygen. This is the fish brown blood disease. Symptoms in this case are similar to when fish suffer from oxygen depletion. Durborow (2000) indicates that low Nitrite concentration at about 0.5 ppm can be problematic when culturing fish.

C. nigrodigitatus although classified as a freshwater species, is described by Dankwa and Gordon (2002) to be able to endure a wide range of salinity making the fish a viable candidate for culture in brackish waters as well.

2.4.6 Nutritional Requirements

Fish need optimum nutrition like any other animal to grow and survive. In natural environments, there is a variety of food available which includes a number of plants and animals. This is summarized by Hasan (2001) that regardless of the type system of culture, sufficient nutrient resources, in amounts and quality affects growth, health and fish reproduction and some other animals in aquatic environments. Natural food in ponds is however not adequate to sustain the fish particularly when densities are high in ponds (Offem *et al*, 2009). Igbinosun and Talabi (1982) clarify that elementary data on the nutrient requirements of tropical fresh and brackish water fish species is very important in putting together balanced pelleted feeds for optimum culture yields.

Protein makes up about 70 percent of the dry weight of fish muscle. Maintenance and growth of fish is achieved through the constant supply of protein. There are a variety of sources of protein but some chief sources for catfish feeds are fishmeal, soybean meal, cottonseed meal, and meat and bone/blood meal. The protein content of most commercial catfish feeds for growing food fish ranges between 28 or 32% protein. Diets comprising lower levels protein are suitable for maximum growth but possibly increase fat in the body (Robinson *et al,* 2006).

Energy like other nutrients makes an essential constituent of fish diets. Balancing dietary energy content when formulating feed is imperative in feed for catfish, though how much is ingested may not be firmly controlled by dietary energy in catfish.

Carbohydrates and lipids (fats and oils) are the chief sources of energy for catfish. (Robinson *et al*, 2000). According to Robinson *et al* (2006), estimates of the energy requirements of catfishes is expressed as a ratio of digestible energy (DE) to crude protein (DE/P), determined by measuring how much weight or protein is gained by fish fed formulated diets with identified amounts of energy. This usually is reported to in 7.4-12 kilocalorie/gram (kcal/g) range. In production of commercial feed, 8.5-9.5 kcal/g as DE/P ratio is considered acceptable. There is a decline in processed yield and rise in fat deposited in fish with high DE/P ratio, lower values otherwise causes fish to grow slowly.

Carbohydrates generally stored in the roots, tubers and seeds of plants represent the most important source of energy. As described by Hasan (2001), Carbohydrates are commonly used for protein sparing when formulating diet because they are found to be a least costly source of dietary energy. According to Robinson *et al* (2006), 25% or higher digestible carbohydrates can typically be included in catfish feed with an added 3-6 % extra carbohydrates mostly present in the form of crude fiber (largely cellulose). Crude fibre is not digested efficiently by catfishes just as other fish so advisable to include quantities as low as amounts less than 5 percent crude fiber (Robinson *et al*, 2000).

Lipids (fats and oils) are known to be a source of easily digestible concentrated energy, providing double the energy from same quantity of carbohydrates. Lipids in the body

of fish are essential in supplying essential fatty acids (EFA), also help in especially fat-soluble vitamin absorption, increase in feed intake and a store of lipids in body tissues improves the flavour of fish. Lipids are concentrated source of less expensive energy compared to protein although not required as a nutrient component in catfish diets. Hasan (2001) explains that the primary need to include lipids in diet formulation is for protein sparing maximization. There is high deposition of fat in fish body when the dietary protein is high affecting the processed yield, quality of product and how the processed products are stored. Sometimes, supplemental lipid is sprayed onto finished feed pellets when needed because high lipid in feeds can make pelletizing challenging. Cowey and Sargent (1979) indicate that optimal growth is achievable in freshwater fish fed diets with 10-20 percent of lipid with the carcass not having excess fat. An acceptable amount of 5-6% of lipids can be included in diets of
Catfish (Robinson *et al*, 2006).

The ash content of fish diet is normally the amount of vitamins and minerals in the diet. In order to achieve normal growth, reproduce and be healthy, vitamins are required in small amounts. According to Robinson *et al* (2006), vitamin premix containing right quantities of required vitamins is included in catfish feeds as supplements and also to take care of losses during processing and storage. Minerals are also required for balancing fluids in the body fluids and the environments they are found in. Catfish absorb minerals in the water they live in and there are some fourteen minerals found to be of high importance to them. Phosphorus particularly is essential because a reasonable amount is needed. Pond water does not provide enough phosphorous and plant sources of feedstuffs also have low quantities. The use of Dicalcium and defluorinated phosphates is common in feeds as phosphorus supplements. A premix of minerals required at low levels (Trace minerals) is used as supplement in Catfish feeds to provide the right amount or go above amounts required in diets. Robinson *et al* (2000) asserts feeds for catfish containing 4% or higher animal protein may not require the inclusion of trace mineral premix.

2.4.6.1 Food and feeding Habits

To efficiently manage fish farms cost effectively, nutritional strategies operative and impacting are necessary and achievable only by way of appropriately understanding which foods and the feeding habits of fish intended for cultured (Offem *et al,* 2009). It is therefore important to research into which foods and the feeding habits of *Chrysichthys nigrodigitatus* to establish the nutritional requirement for effective culture.

Research on the feeding habits of *Chysichthys filamentosus* by Nwadiaro and Okorie (1985) made an assertion that members of the genus *Chrysichthys* in most African freshwaters have their diets comprising of major food items such as Insect larvae, detritus, crustaceans, mollusks, vegetable matter and young fish. Similar observations by Offem *et al* (2009) on the trophic ecology of some fishes of commercial importance in the Cross River, it was generally reported that, bagrid (*Chrysichthys nigrodigitatus*) and clariid (*Clarias anguilaris*) catfishes had fry and fish parts dominating their diet but exhibited a wide food spectrum. The wide food variety exhibited by *C. nigrodigitatus* shown flexibility in trophic levels, ecologically an advantage enabling fish to shift amongst food categories responding to fluctuations in their large quantities also

allowing species to efficiently use a variety of different foods according to Offem *et al* (2008). This assertion agrees with the findings of Yem *et al* (2009) on the food habits of *C. auratus* which stated that, the species are possible bottom dwellers and omnivorous. The work of the latter further explained that the species fed on both plant and animal tissues ranging from detritus to some
unidentified plant tissues. In addition, it was suggested that the species fed both at the bottom and surface of the water considering the range of materials collected in their guts. Some of which was also mud. On the feeding habit of *C. nigrodigitatus*, Akinsanya *et al* (2007) stated that the species is generally omnivorous. An assertion firmly confirmed in the work of Oronsaye and Nakpodia (2005) and Oddson (2006).

It was also reported in the work of Offem *et al* (2009) that *C. nigordigitatus, C. auratus* together with other catfishes and *Oreochromis niloticus* require high energy for sustaining their feeding intensity since they are frequent feeders. Upon review of reports from a number of researches on some freshwaters in Nigeria, Nwadiaro and Okorie, (1985) concluded that members of the genus *Chrysichthys* are bottom feeders. It was further explained that, the presence or predominance of a food item is more a function of their occurrence in the benthos than of preference or selectivity of the species.

Juvenile members of the species have been found to be plankton feeders feeding mainly on zooplankton including copepods particularly *Diaptomus sp* (Ogwumba, 1988). Laleye (1995) explains that feeding tends to be specified by age and size where fish that are bigger feed on decapods. This assertion is confirmed by Offem *et al* (2009) and Lawal *et al* (2010) that *Chrysichthys sp*. in reaction to fluctuation in their abundance and the capacity to effectively use various foods has the ecological advantage of switching between categories. This is also in line with Nwadiaro and Okorie (1985) that, the variability in the composition in the diets of *Chrysichthys* in Oguta Lake appeared to be dictated by changes in food availability than mere seasonality of preference.

Chrysichthys sp. is largely omnivorous, bottom-feeding fish with large proportions of animal component and detritus in their diet and they are adequately pre-adapted for such habits. Also the composition of the benthic community of of the aquatic system is a major determinant in the food spectrum of *Chrysichthys* (Reed *et al.* 1967; Nwadiaro and Okorie, 1985, Lawal *et al*, 2010).

2.4.6.2 Optimum protein requirements

Protein considered most vital single nutrient according to Oyelese (2006b), is required for growth in large quantities. According to Kausshik and Medale (1994), fish need dietary protein for growth, energy and body maintenance. As quoted by Diyawere *et al* (2009), a good step towards the development of feeds that are cost effective for use on farms is knowing the required protein for maximum growth of intended fish species and it involves determination of optimum amounts needed to yield maximum growth rates (Sang-Min and Tae-Jun, 2005). This is in agreement with the statement of Hatlen *et al* (2005) that the development of sustainable farming to meet economic and ecological expectations is dependent on knowing the optimal dietary protein level. Seventy percent of the dry weight of fish muscle is protein, most of it from mixture of proteins in feedstuffs. (Robinson *et al*, 2006). According to Robinson *et al* (2006), dietary protein needs of catfish is influenced by size of fish, feed allowance, non-protein energy of diet, quality of protein, availability of natural food management practices applied and water temperature making it difficult to agree on one protein level appropriate for all situations. However, management, some factors in the environment and size of fish is able to influence dietary levels of nutrient for optimum performance according to Jamabo and Alfred-Ockiya (2008).

Hasan (2001) generally suggested that 30-40% of the diet requirement of most omnivorous and herbivorous fishes is to constitute protein for growth, energy production and maintenance of body of species. However, quite a number of researchers have reported dietary protein requirements for African catfish. Jamabo and Alfred-Ockiya (2008) stated 40% dietary protein requirement for *H. bidorsalis* and Fagbenro *et al*. (1992) recommended crude protein 42.5% for *H. longifilis.* Robinson *et al* (2006) also reports 35% protein for fingerlings (less than 20lbs/1,000) and 45-45% in hatcheries for Fry.

2.5 Digestibility

The development of commercial diets expected to be nutritionally balanced has aided in intensely improving fish nutrition in recent years. Nutrition is described as involving the ingestion of food, which is digested and several nutrients absorbed, then the nutrients are transported all through the body for utilization and conversion into tissues in the body. Aquaculture is fast expanding with equal advances in techniques employed in culturing fish. The main challenge now is how to maximize productivity while minimizing impacts on the environment through discharge of waste since there is increase in fish feed use. The specific concern is with how much nitrogen and phosphorus is released from especially intensive systems completely depending on balanced feeds (Gul *et al*, 2007; Ribeiro *et al,* 2012).

According to Gaylord *et al* (2008), assessment of potential aquaculture feedstuff is started with chemical analyses tied with measuring digestibility of ingredients. An essential step to estimate how efficient feedstuff are, was through measuring digestibility described as the portion of the nutrients of energy found in feedstuff not passed out in the faeces (Asad *et al*, 2008). This assertion is emphasized in Bureau and Cho (1999) that, assessment of digestibility is vital in evaluation of an ingredient or feed because generally, digestibility helps obtain adequate measure of the nutritional value and provides a rational basis for the formulation of diets.

According to Ribeiro *et al* (2012), determining the digestibility coefficients is commonly centered on measurements on faeces, fundamentally relying on conditions and methods utilized in digestibility trials. Ability to collecting the required representative sample of faeces, nutrients leaching from the faeces when it is in contact with water and breaking up of faecal matter over time (promoted through aeration and movement of the experimental animals) are some of the listed challenges that technically affect digestibility measurements for aquatic species by De Silva & Anderson (1995). According to Bureau and Cho (1999), it is evidently not feasible to collect all of the feces excreted by a total number of fish put together and measurement of digestibility in fish need thus to depend on collecting a representative sample not having any uneaten feed bits and also use a digestion indicator (indirect method) with many other techniques employed for collection.

Stripping, suction dissection of the lower parts of intestines to collect faeces is somewhat the most extensively used technique. However according to Cho *et al*, (1982), with the use of this technique, digestibility of nutrients, especially protein is often underestimated due to endogenous materials which would have been absorbed before faces is excreted contaminating samples. Overestimation of values is also possible with the method of siphoning from the bottom of tanks since there can be leaching of nutrients when fish movement cause faecal matter to break up. In a technique introduced by Smith (1971), fish are immobilized in small metabolic chambers, usually force fed and their faeces collected in the water. Fish often regurgitate under these condition showing negative protein and energy balances raising question on the digestibility estimates (Bureau and Cho, 1999). If leaching is to be avoided, the fish would have to be taken out of the water and using a technique such as dissection to remove faeces from distal regions of the intestine.

Fish species and feed stuff have varying apparent digestibility coefficients (ADC). Determining the ADCs of different feedstuffs is imperative for including optimum levels in formulated fish diets and to allowing efficient substitution of ingredients aimed at maximum growth (Asad *et al*, 2008). Maina *et al*, (2002) explain that protein and energy digestibility values from literature are used as basis in the formulation of diets for intensive fish culture.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Survey on indigenous knowledge of *Chrysichthys nigrodigitatus*

The aim of this survey was to assess fish farmer knowledge on the culture and management of the species. Having established a working relationship with farmers through an on-going AquaFish CRSP project, twenty-five (25) Fish farmers were identified in the Ashanti and Brong Ahafo Regions of Ghana from a list of participants in the Aquaculture and Environment Workshop organized in collaboration with the Department of Fisheries and Watershed Management, KNUST and Virginia Polytechnic Institute and State University, Blacksburg, USA. Out of this number, only eight (8) farmers cultured other indigenous species in addition to the traditional Tilapias and Catfishes (*Hetrobranchus sp. and Clarias sp.*). Five (5) farmers out of the eight (8) earlier identified in Kumasi and its environs were available for focus group discussion to ascertain the knowledge on the species.

3.2 Feed trial of *Chrysichthys nigrodigitatus*

The goal of this experiment was to investigate the effect of varying dietary protein levels on the growth performance and feed utilization of *Chrysichthys nigrodigitatus.* The experiment was run for eight weeks in tanks. Fish were conditioned two weeks prior to the commencement of the experiment to enable them to adapt to their new environment and also the formulated diet (control). The fish were stocked in experimental tanks two week before the experiment started. Mean initial weight 16.30 ± 0.07 g of fish were stocked randomly at 12 fingerlings per tank in triplicates per treatment.

3.2.1 Experimental Facilities and Fish

This study was executed at the Department of Fisheries and Watershed Management Laboratory, Faculty of Renewable Natural Resources (FRNR) of the Kwame Nkrumah University of Science and Technology (KNUST). A tank system consisting of twenty (20) glass tanks (60 L) were utilized in the experiment. Underground water had been supplied to the flow through tank system with a flow rate maintained at about 7 mL sec-1 by an overhead tank. The rate of flow was later increased to 12 mL sec-1 in week five (5) of the experimental period. In the third week of the experiment water in the rearing tanks was aerated using air stones connected to a blower.

Maintaining a photoperiod of 12 hours Light: 12 hours Darkness with artificial lights from six (6) pairs of fluorescent tubes and ten (10) incandescent bulbs, natural light cycle was simulated from 06:00 to18:00 hours GMT.

Weekly water quality parameters measured (mean ± SD) in the period of the experiment were: temperature, 26.76 ± 0.02 ^{o}C; pH, 6.61 ± 0.02; dissolved oxygen, 4.04 ± 0.08 mg L -1; salinity, 0.09 ± 0.00 and ammonia, 0.01 ± 0.01 mg L^{-1}

Chrysichthys nigrodigitatus fingerlings were purchased from fishermen who collected the fish from the Volta Lake at Akuse in the Eastern Region, Ghana and transferred into four (4) hapas mounted in a pond at the Faculty of Renewable Natural Resources (FRNR) research farm (Plate 3.1). Fish were later transferred into the experimental tanks at the FRNR fish laboratory. In all 144 fingerlings were used in the experiment (Plate 3.2). There were a total of 12 fish per tank after distribution. Fish were acclimated for 11 days before the feeding trial begun. Commercial fish feed of 42% protein for catfish was fed to fish throughout this period.

Plate 3.1 Hapas for holding *C. nigrodigitatus* from Akuse at the FRNR research farm

Plate 3.2 Experimental setup showing tanks for holding *C. nigrodigitatus* juveniles at Faculty of Renewable Natural Resource

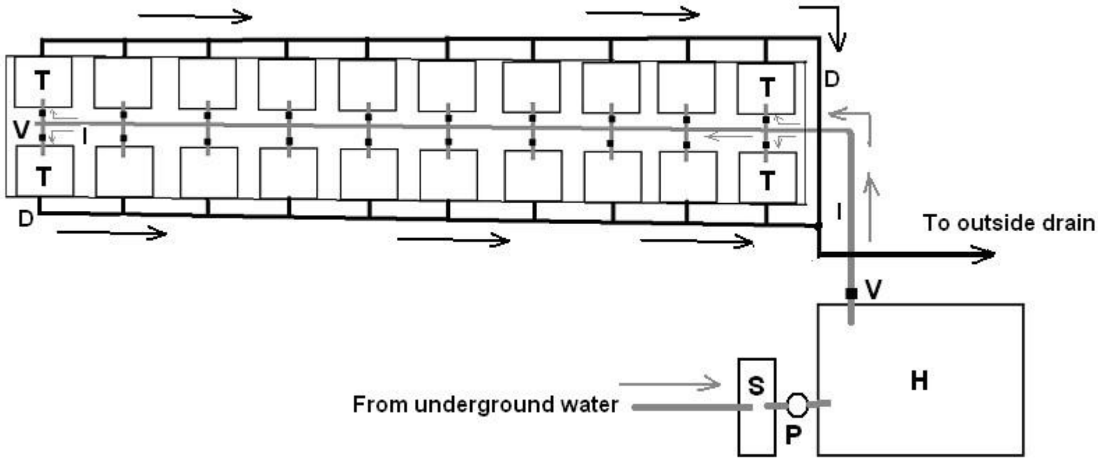

Figure 3.1 Flow through water system used for the studies Key: H = Header tank; I = Inlet pipes, S = Settling tank T = Experimental tanks, P = Pump; D = Drainage Pipes, Direction of water flow (Adapted from Yeboah-Agyepong, 2010)

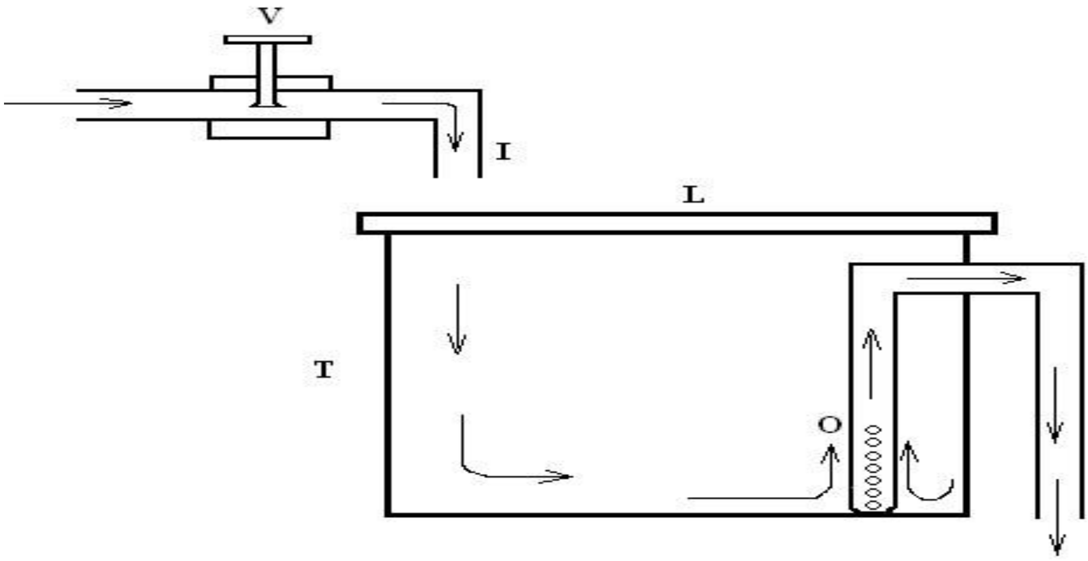

Figure 3.2 Experimental / Rearing tank Key: L = Tank lid, T = Tank; O = Inverted Drainage Pipe, I = Inlet pipe; Direction of water flow (Adapted from Yeboah-Agyepong Mark, 2010)

Plate 3.3 ***Chrysichthys nigrodigitatus*** **used in the experiment**

3.2.2 Experimental Facilities and Fish

Five experimental diets containing varying crude protein (CP) levels of 30%, 35%, 40%, and 45% using locally available ingredients were formulated. All diets were formulated to contain 10% lipid and 18kJg^{-1} energy (on as-fed basis). Table 3.3 gives the experimental diets, formulations and what they constitute. The main sources of protein in the diets were from soybean meal and fishmeal in a ratio of 2:1 respectively. For the carbohydrate source, rice bran and wheat bran were added with cassava flour as a binder. Di-calcium phosphate and vitamin premix (Table 3.2) were added for vitamin and mineral supplements whiles salt was added for taste and low levels of minerals like iodine and sodium. Lipid component in the diets was derived from palm oil and also to provide energy. The various ingredients were milled at the local market in Ayeduase near the KNUST Campus. The inert indigestible marker included in the diet was chromic oxide for apparent digestibility coefficients (ADC) determination (De Silva and Anderson, 1995). Ingredients were weighed according to the formulation (Table 3.3) and hand mixed thoroughly in bowls to obtain a homogenous mixture. The required proportion of palm oil was added and warm water at 30% of the total dry components and carefully mixed into a dough-like paste before pelletizing using a meat mincer (Sanyo meat mincer MG-5000K). An oven (Gallenkamp Hotbox Oven with fan) was used in drying moist pellets at 60°C. Feed, now dried and pelleted were kept in air tight polythene bags in a freezer (-20°C) at FRNR laboratories. All diets formulated were subjected to proximate analysis to determine their nutrient composition.

Plate 3.4 Sanyo meats Grinder Mincer fitted with 3mm die for pelletizing feed

Formulated diets were allocated randomly to 12 experimental tanks in triplicates. Fish were fed to satiation for two weeks and later fixed at 3% of fish body weight daily. Feeding (by hand) was done twice each day at 07:00 and 16:00 GMT except on sampling days when fish were fed after the sampling.

The feed trial lasted a period of 10 weeks. Fish were weighed with an electronic scale

(Sartorius BP 4100, AG Gottingen, Germany) to the nearest 0.01g and counted in batches at the start of experiment, and then weekly and mean weights of fish determined per tank.

Fish were collected with scoop nets, allowed to drain for a few seconds and dabbed with a dry towel to reduce error due to water adhering to fish skin. The fish was transferred into a tarred, water filled container with weights recorded to the nearest 0.01g. Quantities of feed to be fed were adjusted weekly to reflect new weights of fish. Tanks were cleaned by siphoning uneaten food and waste with water hose.

Table 3.1 Proximate Composition (%) of Feed Ingredients used in diet formulation

Ingredient	Protein	Lipid	Fiber	Ash	Moisture	NFE	Gross Energy ($KJ\ g^{-1}$)
Fish meal	70.33	11.28	0.65	13.11	8.83	4.63	21.85
Soybean Cake	45.48	7.53	4.75	6.77	11.15	35.46	19.81
Rice Bran	8.69	11.55	16.29	11.08	8.80	52.39	15.62
Wheat bran	18.93	8.15	7.87	4.68	12.47	64.12	12.83
Cassava Flour	0.84	0.41	2.05	2.65	11.97	82.08	

Table 3.2 Composition of Vitamin and Mineral premix used in diet formulation

Vitamins, Pro-vitamins and well-defined substances having similar effect	
Vitamin A	80,000 U.I
Vitamin D3	15,000 U.I
Vitamin E (contenido en alfatocoferoles)	25 mg

Vitamin K3	10 mg
Vitamin B2	20 mg
Vitamin B12	0.05 mg
Folic Acid	5 mg
Nicotinic Acid	80 mg
Calcium panthotenate	20 mg
Choline cloruro	500 mg
Compounds of trace elements	
Manganesium (as mono-hydrate sulphate mangnesium)	500 mg
Zinc (as Zinc oxide)	400 mg
Copper (as penta-hygrate sulphate copper)	45 mg
Cobalt (as hepta-hydrate sulphate cobalt)	1 mg
Iodine (as potassium iodine)	10 mg
Selenium (as sodium selenium)	1 mg
Antioxidants	
Butylated Hydroxytoluene (B.H.T)	100 mg
Carrier:	
Calcium, carbonate q.s.p	0.025 kg

Manufactured by DEX IBERICA, S.A. NUTRIDEX LAYER PREMIX® (Premixture)

Table 3.3 Composition of Experimental Diets (g/kg) fed to *Chrysichthys nigrodigitatus*

	CP30	CP35	CP40	CP45
Ingredients	1	2	3	4
Fish meal	237	298	350	407
Soy bean Meal	188	222	275	322
Rice Bran	305	230	150	80
Wheat Bran	155	135	110	76

Salt	10	10	10	10
Palm oil	20	20	20	20
Di Calcium Phosphate	20	20	20	20
Cassava Flour (Binder)	20	20	20	20
Vitamin & mineral Premix	40	40	40	40
Chromic Oxide	5	5	5	5
Dry matter	952.1	955.0	966.6	967.3
Crude protein	320.8	346.1	428.1	470.9
Crude lipid	90.7	88.4	106.9	144.8
Crude fibre	77.3	60.2	52.2	39.0
Ash	159.1	159.1	159.1	181.8
Nitrogen free extract	304.2	301.2	220.3	130.8
	17.4	17.9	18.4	19.1
Gross energy, (kJ g^{-1})	18.5	19.3	23.3	25.1
P/E ratio (mg protein/kJ GE)				

Plate 3.5 Pelleted experimental diets (green coloration due to the inclusion of Chromic oxide) fed to *Chrysichthys nigrodigitatus*

3.3 Methods of Proximate and Chromic Oxide Analysis

Proximate Analysis of the whole fish body composition, ingredients, diets formulated and Chromic Oxide were carried out at the laboratories of the Department of Food Science Technology and the Faculty of Renewable Natural Resources (KNUST) according to the methods of AOAC (1990). All analyses were done in triplicates.

3.3.1 Moisture Content (MC) Determination

Approximately 2 grams of sample was weighed into glass crucibles and oven dried for five (5) hours at 105°C (Gallenkamp Hotbox Oven with fan size 1). Dried sample were cooled down inside a desiccator and weighed again. The reduction in weight of the final weight from the initial weight was recorded as the moisture content of the sample expressed in percentages of the initial weight.

3.3.2 Ash Content (AC) Determination

A Stuart Scientific Muffle furnace was used in incinerating approximately 2 g of sample weighed prior into ceramic crucible at 600°c for two hours. Change in the final and initial weight of empty crucible and crucible containing the residue after incineration represented the ash. This was then expressed as a percentage of the weight of the original sample. The ash content is measured as the total inorganic matter in the sample.

3.3.3 Crude Protein (CP) Determination

The Kjeldahl method was employed to estimate the Crude Protein (CP) in ingredients, feed, fish and faecal matter samples. Approximately 2 g sample was digested in concentrated sulphuric acid with a selenium based catalyst tablet (contains 3.5 g potassium sulphate and 3.5 mg Selenium). The digested sample was distilled with Kjeldahl distiller after reacting with 40% Sodium hydroxide. The liberated Nitrogen (N) gas from the mixture was received into 2% boric acid and quantified by titration in triplicate. The CP was determined by the formulae (N x 6.25).

3.3.4 Crude Lipid (CL) Determination

The Crude Lipid in the sample was estimated by a method of solvent extraction using Soxhlet extraction. Approximately 2 g of dried samples was weighed into thimbles. Petroleum-ether 40-60^{0}C (contains approximately 2% n-Hexane) was added to a preweighed flask. The thimbles were placed into the unit. A condenser with three glass balls was connect to the soxhlet extractor and reflux for 16 hours on low heat setting with mantle at a condensation rate of 2 to 3 drops per second. The flask and extractant were heated for 30minutes in an oven at 103^{0}C before weighing to determine the weight of the lipid, expressing it as a percentage of the original sample.

3.3.5 Crude Fibre (CF) Determination

Approximately 2 g of defatted sample was used for crude fibre determination by successively boiling the sample in 1.25% H_2SO_4 and 1.25% NaOH. The residue were washed and placed in crucibles for ashing in the muffle furnace at 550^{0}C and crude fibre in the defatted sample recorded as a percentage of the initial undefatted sample

3.3.6 Nitrogen Free Extract

The Nitrogen free extractive was estimated by deducting the total of moisture, crude protein, crude lipid, ash and crude fibre from 100.

3.3.7 Gross Energy (GE) Determination

The gross energy for ingredients, diets and fish body was estimated by summing the energies of the individual ingredients and diets.

However the gross energy contained in faecal matter was estimated using an Adiabatic bomb Calorimeter (PHYWE P3021401 D-37070, Göttingen) and benzoic acid as standard. Approximately 1g of dried sample molded into a tablet using a briquette press was combusted in a chamber pressurized with oxygen and the resulting heat measured by increase in temperature of water surrounding the bomb. Following the instructions in the operation manual from the manufacturer, the energy content of the sample is automatically determined by the bomb calorimeter.

3.3.8 Chromic Oxide Analysis

Feed and faecal matter were analysed to determine the chromic oxide content referring to techniques of Furukawa and Tsukahara (1966). In this method, the sample was digested by concentrated nitric acid after which chromic oxide with 70% perchloric acid was used to oxidize. A spectrophotometer (UVmini-1240, UV-VIS Spectrophotometer, Shimadzu) reads the orange colour change at 350nm against distilled water after chromium III is oxidized to chromium IV.

Approximately 1g of sample was weighed into a Kjeldahl flask then 5 ml of concentrated nitric acid added to the flask and mixture boiled (using an electric 60 mantle) gently for about 20 minutes (taking care not to boil dry). After cooling the sample, 3ml of 70% perchloric acid was added to the flask. The mixture was then gently heated again until the solution turned from a green to an orange colour after which it was left to boil for a further 10 minutes to ensure oxidation was complete.

The solution was now poured in a 100 ml volumetric flask and diluted to volume. With the use of the spectrophotometer determined at 350nm against distilled water absorbance of the solution. Chromic III oxide was calculated according to the formula:

$$\text{Chromic oxide (\%)} = \left[\frac{\frac{(\text{absorbance} - 0.0032)}{0.2089}}{\text{Sample weight}} \right] \times 100 \qquad (1)$$

3.4 Water Quality

Temperature (°c), pH, dissolved oxygen (mg/l), ammonia, salinity and nitrite-N were the parameters for determining water quality monitored through the period of experimental. Data was recorded as measured per tank. Temperature and DO were monitored with a YSI Environmental 550A model multi parameter probe. Ammonia was measured with a LaMotte Ammonia Nitrogen Test Kit (SL-PAN 3315) by the Octa-Slide method and Nitrite-N was measured with a LaMotte Octet comparator and Bi-Color reader (2151). pH was monitored with a Eutech Instruments waterproof pHTeste 20 and Salinity was measured with a Hanna HI 9828 multi parameter probe.

3.5 Analysis of Biological Parameters

Performance of *Chrysichthys nigrodigitatus* fed with experimental diets during the experimental period was measured by selected parameters which are growth, food conversion and protein efficiency ratios.

3.5.1 Growth

Growth of fish over the experimental period was measures by the differences in weight of fish in each tank. Weight of fish per tank at the start of the experiment had been recorded as the initial weight (W_o) and the weight at each sampling days as the final weight (W_t) of fish per hapa.

The following growth parameters were calculated from the data acquired:

Weight gain (g) = Wt –Wo

Specific growth rate (%/d) = $100^* (\text{Ln } W_t - \text{Ln } W_o)/ t$

Where W_o = initial weight at the beginning of experiment; W_t = final weight at day t. t = duration of experiment in days (t = 70 days).

3.5.2 Feed Conversion Ratio (FCR)

Expression of the amount of food utilized per unit increase in fish size (Delinće, 1992). Calculated as the ratio of the feed quantity fed over the increase of biomass during the experimental period

FCR (g/g) = $F/ (W_t - W_o)$

Where W_t = final weight at the end of experiment; W_o = initial weight at the start of the experiment; F = dry feed fed

3.5.3 Protein Efficiency Ratio

The protein efficiency ratio (PER), of the tilapia given the experimental diets was calculated as: Protein efficiency ratio (g/g) = $(W_t - W_o)/ F^* Pf$

Where W_t = final weight at the end of the experiment; W_o = initial weight at the start of the experiment; F = total feed fed during the experimental period; Pf = protein content of feed.

3.5.4 Digestibility

Chrysichthys nigrodigitatus fingerlings were given the experimental diets in triplicates to satiation in two (2) portions each day (07:00 and 16:00 GMT) for eight (8) weeks prior to faecal collection. Two (2) hours after the evening feeding (18:00 GMT), all experimental tanks were cleaned by siphoning all uneaten feed and faecal matter, and three-quarters (3/4) of the water in the tanks was exchanged with fresh water. Faecal matter for analysis was collected early each morning at 06:00 GMT and at 15:00GMT (An hour to feeding). Faecal matter siphoned into 12 different containers were immediately centrifuged with a Universal 16A, Centrifuge (Hettich D-78532, Tuttingen) at 2500U/min for 15 minutes and discarded the supernatant. Settled solids of faeces which were wet were oven dried at 60^0C for 24h. It was further pulverized and stored until quantity obtained was enough for chemical analysis.

Plate 3.6 Faecal matter collection

3.5.4.1 Apparent Digestibility Coefficient Determination

The following is how the apparent digestibility coefficients (ADC) for the nutrients of the diets were estimated (Bureau *et al*., 1999):

$$ADC\ (\%) = 100[1-(F/D \times Di/Fi)] \quad (2)$$

Where D and F are the concentrations of nutrient in the diets ingested and fecal output, respectively; D_i and F_i are the concentrations of the Chromic (III) Oxide level the ingested diet contain and faecal output, respectively. The nutrients were defined as crude protein (CP), crude lipids (CL) and gross energy (GE).

3.5.5 Body Composition of Fish

Proximate analysis of whole body before then after experiment was used to estimate fish body composition. The proximate analysis followed methods described in Section 3.3 with moisture, crude protein, crude lipid and ash evaluated and expressed as percentage of fresh weight.

3.6 Statistical Analysis

All data obtained including Growth, feed utilization, whole body composition and Apparent Digestibility Coefficients (ADC) were subjected to one-way Analysis of Variance (ANOVA) followed by Tukey's posthoc test to determine significant differences between individual treatments. Results are presented as means standard error of the mean _SEM (n=3) at significance levels of $P< 0.05$. All statistical analyses were performed using (SPSS 16.0, SPSS Inc., www.spss.com). To select a dose-reponse model for optimum protein required in diets for juvenile *C. nigrodigitatus* based on percentage body weight gain (BWG%), three models were compared: 1) a second-order polynomial regression, 2) a third-order polynomial regression, and 3) a broken stick or piecewise regression. All model forms are defined by Neter *et al* (1996). Comparing alternate models were aimed at finding the model that best fits the data. Models were compared in an information-theoretic framework based on the Akaike Information Criterion with correction for small sample size (AICc) and model weight (w i), representing the proportional weight of evidence supporting each model (Anderson, 2008). For the polynomial regressions, the x variable (crude protein level) was centred by subtracting the mean value from each observation to effectively reduce multicollinearity among x, x2, and x3 (Neter *et al*, 1996).

CHAPTER FOUR

4.0 RESULTS

4.1 Survey on Indigenous Knowledge of farmers on *Chrysichthys*

Results from the survey indicated that aside *Chrysichthys spp.* other indigenous freshwater fish species cultured include *Heterotis niloticus* and *Parachana obscura,* on a smaller scale compared to the traditionally cultured Tilapia and the African catfish (*Clarias gariepinus*). Only three (3) respondents out of the twenty-eight (28) farmers identified and interviewed in the Ashanti region cultured *Chrysichthys* species.

Plate 4.1 Author with one of the selected farmers

4.1.1 Native distribution of *Chrysichthys* in Ashanti Region, Ghana

Information obtained from the farmers during the survey suggested that the source of *Chrysichthys* as seed for culture on the farms was the River Offin. Fingerlings were collected from the river and transported to the ponds. *Chrysichthys species* are known in the local language as *Kontro* (Akan) and *Blolovi* (Ewe).

4.1.2 Ecology of Chrysichthys

The ecology of *Chrysichthys species* was described by their habitat requirement and trophic level.

- Habitat requirement

Two of the farmers stated that the species are bottom dwellers. The other farmer however had no knowledge of the natural habitat of *Chrysichthys*. They further explained that the fish are normally found at rocky bottoms and in holes created in especially bamboo. All three fish farmers confirmed that the fish species survive under pond conditions and are mostly found at the surface of the water in the mornings and at the bottom at nights.

- Trophic Habits

All three (3) farmers acknowledged that *Chrysichthys* is an omnivorous bottom feeder. They feed on detritus, vegetation, insects and other smaller aquatic organisms in the ponds. Two of the farmers have tried to feed the species with compounded feed successfully, however one farmer observed that the fish only fed on the compounded feed when they had been starved over a period. The other farmer has however depended on the natural production in the pond as food for the species.

4.2 Life and History Traits

4.2.1 Growth

To assess growth, questions were asked pertaining to the size at stocking, stocking rate, length of growth period and the size at harvest. Two of the farmers explained that fish obtained from the wild range between 5-10 g. The other farmer however stocked larger sizes about 200 g and had not harvested at the time of interview. None of the farmers had records of the rate at which the fish were stocked. The two (2) who had harvested previously stated the size at harvest ranged from 600g-1kg after six (6) months of culture.

4.2.2 Site and mode of reproduction

According to the information gathered from the farmers, the site for reproduction for *Chrysichthys spp.* is the rock bottoms on which they dwell. They explained that eggs were laid in the crevices of the rocks and in holes especially bamboo. They have been observed to spawn in the ponds with the young ones usually seen at the surface of the pond water. None of the farmers could describe the mode of spawning in these species but stated that the young ones were normally found in ponds from the month of October to December. Two of the farmers added that spawning is encouraged in clean water with vegetation at pond margins and good feed. Ponds with rocky bottoms also provided substrates for reproduction. All the farmers confirmed the young ones survive well under the pond conditions.

4.3 Nutritional studies

4.3.1 Acceptability/Palatability of Formulated diets

To assess the palatability of experimental diets, fish were directly observed during feeding to ascertain general behaviour and feeding responses. There was not much variation in the general response of fish during feeding. All fish generally fed at the bottom of tanks. Fish adapted to feed within the first two (2) days of the start of the experiment. However, feeding activity took longer time of about 5-10 minutes with some leftover feed in tanks.

4.3.2 Growth Performance

Growth performance of *Chrysichthys nigrodigitatus* fed formulated diets containing varying levels of protein for ten (10) weeks is given in Table 4.1. The results indicated a general increase in growth at the end of the experiment. The Final body weight (FBW), weight gain (WG), Specific growth rate (SGR) and percentage body weight gained (%BWG) of *C. nigrodigitatus* that received experimental diets showed similar trends. The highest values were recorded in fish fed diets having 40% protein inclusion level followed by fish that took 45% levels of protein. The lowest values were recorded in the fish that received the 30% protein diet with fish that received the 35% protein diets doing slightly better as shown in Table 4.1. The FBW, WG, %BWG and SGR recorded for the fish fed the 40% protein diets were 23.32g, 7.22g, 44.88% and 0.53%/day respectively. The 35% protein diet did slightly better with 20.40g, 4.06g, 24.85% and 0.32%/day than fish fed the 30% protein diet which recorded 19.91g, 3.49g, 21.25% and 0.28%/day respectively. Means recorded did not differ significantly between the final body weight (FBW) of 40% and 45% protein diets. However, values for the 40% diet were significantly different from the 30% and 35% diets at $p < 0.05$. The FBW of fish fed diets with protein of 45% did not differ significantly from 30% and 35% protein diets at $p < 0.05$. Comparable trends were noted for the Weight gain (WG), Percentage body weight (%BDW) and Specific growth Rates.

Table 4.1 Growth performance and feed utilization of *Chrysichthys nigrodigitatus* fed the experimental diets

	Experimental diet			
Parameter	CP30	CP35	CP40	CP45
Initial weight (g)	16.42 ± 0.05	16.34 ± 0.07	16.10 ± 0.27	16.35 ± 0.10
Final weight (g)	19.91±0.31^{b}	20.40± 0.48^{b}	23.32 ± 0.33^{a}	21.67± 0.72^{ab}
Weight gain (g)	3.49 ± 0.36^{b}	4.06 ± 0.42^{b}	7.22 ± 0.31^{a}	5.31 ± 0.64^{ab}
Weight gain (%)	21.25 ± 2.29^{a}	24.85 ± 2.46^{a}	44.88 ± 2.29^{b}	32.46± 3.78^{ab}
SGR (%.day^{1})	0.28 ± 0.03^{b}	0.32 ± 0.03^{b}	0.53 ± 0.03^{a}	0.40 ± 0.04^{ab}
Feed intake (g)	22.11 ± 0.12	22.18 ± 1.30	23.83 ± 0.24	21.27 ± 0.67
Feed conversion ratio	6.48 ± 0.67^{b}	5.63 ± 0.83^{ab}	3.32 ± 0.18^{a}	4.13 ± 0.56^{ab}
Protein intake (g)	7.09	7.12	7.64	6.82
Protein efficiency ratio	0.49 ± 0.05	0.54 ± 0.09	0.71 ± 0.04	0.53 ± 0.07
Survival (%)	80.55 ± 2.78	83.33 ± 9.62	77.78 ± 2.78	88.89 ± 5.56

Mean values in the same row with different superscripts are significantly different ($P < 0.05$) and Values are presented as means ± SE (n = 3)

Third-polynomial regression analysis based on WG [y = -0.105(x – 39.15)2 – 0.364x + 17.1346; R2 = 0.7830; x = dietary protein levels (%), y = WG (%)] showed that the optimum required protein for *C. nigrodigitatus* juvenile was 42.9%.

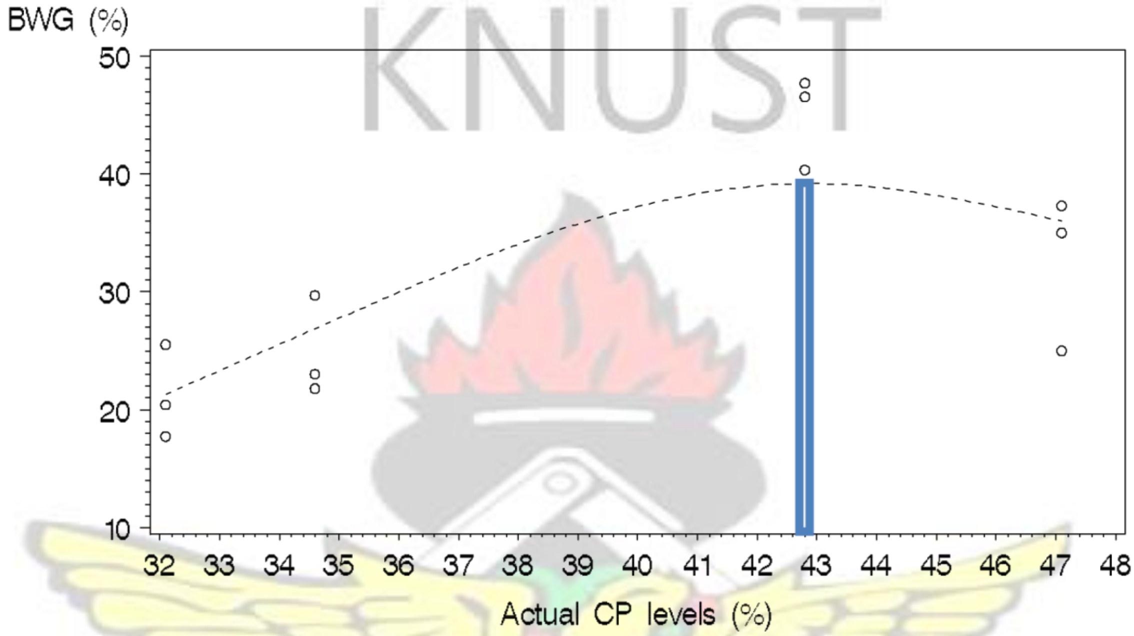

Figure 4.1 The relationship between weight gain (%, y) and dietary protein levels (%, x) in juvenile C. nigrodigitatus (Xmax = 42.9 %) grown for 70 days

4.3.3 Feed Utilization

Feed conversion ratios (FCR) and Protein efficiency ratios (PER) measured were to determine the utilization of feed by fish that had been fed the dietary treatments. The FCR recorded in fish fed the 40% protein diet was best performance having the lowest value of 3.32. This was followed by fish fed 45% protein diets with 4.13, then fish fed 35% protein diets with 5.63 and the highest value representing the worst performance was 6.48 recorded in fish fed diets containing 30% inclusion level of protein.

Differences between means recorded for fish fed 40% protein diets were significant at p<0.05 from means recorded in fish fed the 30% inclusion level diets. However, there were no differences between values recorded for 40%, 45% and 35% protein levels and the same trend observed for 30%, 35% and 45% diets. The highest Protein Intake (PI) was recorded in the 40% protein fed fish and the lowest in fish fed 45% inclusion level diet as presented in Table 4.1.

4.4 Feed Digestibility

Apparent digestibility coefficients (ADC) recorded for protein, lipid and dry matter contents in the diets are presented in Table 4.2. Crude lipid digestibility was fairly higher than the other nutrients. The least digestibility was observed in the dry matter (Table 4.2). Differences between mean values recorded for crude protein and dry matter were not significant. ADC of crude lipid increased with increasing inclusion level of protein ranging between 83.41% and 91.33%. The ADC for crude lipid recorded for the 45% inclusion level was significantly higher than that recorded for 30% inclusion level. There were no significant difference between the 45%, 40% and 35% inclusion levels. Similar observations were made for 30%, 35%, 40% inclusion (P<0.05). Crude protein digestibility was highest in the 40% inclusion level and lowest in 30% protein level.

Table 4.2 Apparent digestibility coefficients (%) of main nutrients in diets for juvenile *Chrysichthys nigrodigitatus* fed varying protein levels for 70 days

	Crude protein levels in the diet (%)			
	CP30	CP35	CP40	CP45
Crude protein	70.6 ± 4.8	71.6 ± 4.7	72.6 ± 1.1	71.8 ± 1.5
Crude lipid	83.4 ± 2. 7[b]	88.8 ± 0.3[ab]	88.9 ± 1.9[ab]	91.3 ± 0.9[a]

Dry matter	49.3 ± 2.8	53.1 ± 2.6	55. 8 ± 2.4	56.4 ± 0. 6

Values are presented as means ± SE (n = 3) and values within the same row with different letters are significantly different (P< 0.05).

4.5 Body Composition

Table 4.3 shows the whole body composition of *Chrysichthys nigrodigitatus*. Means recorded for all dietary treatments on the moisture, ash and protein were not different significantly at $p<0.05$. Moisture content of flesh generally decreased with the rise in protein content in fish diets but the differences were not significant at $p<0.005$. Conversely, protein contained in the fish flesh improved with the increase protein inclusion level of diets. Crude Lipid and Ash in fish flesh subjected to the various treatments showed similar trends of an increase with increasing protein inclusion level from 30-40% and a decline at 45% protein inclusion level. The highest values for both nutrients were recorded in fish fed 40% protein diets with 5.00 ± 0.31and 4.96 ± 0.75 for crude lipid and ash contents respectively. Fish fed 45% protein diet followed with values better than those fed 35% and 30% in decreasing order. Crude lipid content of fish flesh from the 40% protein treatment was significantly different from those from the 30% protein treatment but not different from those from 35% and 45% protein inclusion levels. Similarly, values recorded for 30% protein treated fish were not different significantly from those from 35% and 45% inclusion level diets but fish from 40% protein treatment at $p<0.05$.

Table 4.3 Whole body composition (% wet weight) and energy of juvenile *Chrysichthys nigrodigitatus* fed varying levels of protein for 70 days

Components	Crude protein levels in the diet (%)			
	CP30	CP35	CP40	CP45
Moisture content	75.66 ± 0.61	75.56 ± 1.67	73.69 ± 0.23	73.26 ± 1.18
Crude protein	15.77 ± 0.83	16.39 ± 1.22	19.12 ± 0.30	19.37 ± 0.94
Crude lipid	2.83 ± 0.46^{b}	4.05 ± 0.54^{ab}	5.00 ± 0.31^{a}	4.23 ± 0.33^{ab}
Ash	3.58 ± 0.15	4.34 ± 0.65	4.96 ± 0.75	4.65 ± 0.22

Values are means ± SE (n = 3) and values within the same row with different letters are significantly different (P< 0.05).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Survey on Indigenous Knowledge of farmers on *Chrysichthys nigrodigitatus*

Knowledge on the biology of *Chrysichthys nigrodigitatus* is imperative to manage and sustainably utilize the stock. *Chrysichthys nigrodigitatus* (Lacepède 1803) is silvery in colour and found in rivers across West Africa. In Ghana it forms a significant portion of the catch at most landing sites on the Volta Lake. It is known in the local language as Kontro (Akan) and Blolovi (Ewe). Work by Dankwa *et al*

(1999) showed that the species is found in the Volta and Offin and their tributaries. This was confirmed from the interviews with farmers who obtained seed from tributaries of River Offin in the Ashanti Region.

The farmers further stated that the species is a bottom dwellers found on rocky bottoms and in holes especially in bamboos, an assertion which differs from Ezenwa (1981), who reported that the species thrive abundantly on soft muddy grounds usually at the mouth of mangrove belts where roots and tangles of plants exist. It is recorded in Erondu, (1997) that *C. nigrodigitatus* falls under the nest building group and that during reproduction; brooders formed breeding couples and spawned in hollow cavities of rocks which they find at the banks of rivers and lakes. Personal observation at landing sites with fishermen confirms that the species are best caught with bamboo traps placed the near bottom rivers especially during the breeding season. This confirms that the species are basically bottom dwelling with periodic activity in the open waters especially during daytime.

With regards to their feeding habits, the farmers asserted that the fish fed on insects, larvae and detritus at pond and river bottoms just as reported in earlier studies on the stomach content of the species in some rivers in Nigeria (Nwadiaro and Okorie, 1987; Yem *et al*, 2009). Work done by Oranseye and Nakpodia (2005), Oddson (2006), Yem *et al* (2009) and Francis and Elewu (2012) all confirm that *Chrysichthys* is omnivorous. Adewolu and Benfey (2009) record the species ability to accept formulated feed under captivity.

5.2 Life and History Traits

Specific knowledge on the stocking size, stocking rate and size at maturity was barely known by farmers. Although Pagni *et al* (2008b) suggested the fish had remarkable growth rate, no literature was found that specifically stated a matured size of *Chrysichthys nigrodigitatus.* By estimate, the farmers reported the sizes at harvest being greater than 500 g after six (6) months.

Seed was mostly collected from bamboo traps set at bottom of rivers. Farmers however, believe that the fish species spawn in similar sites. Implying that reproduction mostly takes place in rock crevices and holes at pond and river bottoms. In the ponds, the farmers could not clearly observe and describe spawning activities but reported seeing juveniles at the water surface in shallow portions especially early mornings which survived under pond conditions. These juveniles are normally observed in ponds from the month of October to December a confirmation studies by Erondu (1997) that *C. nigrodigitatus* is a seasonal breeder and spawns in October and November.

5.3 Nutritional Studies

5.3.1 Acceptability, growth performance and feed utilization

According to Siddiqui and Khan (2009) maximization of growth in many fish species is achieved when the required optimum dietary protein is supplied for the release of acceptable quantities of amino acids. The requirement of protein in fish has been defined as the quantity of protein needed to achieve maximum fish growth.. For every surplus protein included in diets, only a portion is used in producing new proteins for growth and with the leftover converted to energy only contributing to increase in cost of feed and ammonia nitrogen excreted into the surroundings. Thus, it is important in aquaculture production and environmentally advantage to estimate the optimum protein a fish requires. (Erondu *et al*, 2006; Siddiqui and Khan, 2009; Akpinar *et al*, 2011).

5.3.2 Growth Performance

The present study indicated that the level of protein in the diets affected growth performance. Growth, as expressed by percentage BWG and SGR, increased with increasing in dietary protein level from 32.1%–42.8% crude protein (Table 4.1). This pattern follows a similar trend in the report from Adewolu and Benfey (2009) on the study of protein requirements for juvenile *C. nigrodigitatus* when the protein inclusion levels considered ranged from 20-35%. On the other hand fish fed a diet containing 45% protein performed better after those that fed on 30-35% protein diets. The enhanced growth with increasing dietary protein content in this research coupled with increase in feed consumed and fish protein intake from 30%-40% inclusion levels and a decline at 45% protein level (Table 4.1).

Supporting the growth performance observed in this study with the result from the third-polynomial regression analysis shows that, the optimum level of protein in diets for *C. nigrodigitatus* juvenile is 42.8% when fish meal and soybean meal were included as the main source of protein (Figure 4.1). This is comparable to the results for diets of omnivorous fish, for example, bagrid catfish, *Mystus nemurus* 44%; (Ng *et al*, 2001); silver perch, *Bidyanus bidyanus* 42.2%;(Yang *et al*, 2002); black sea bream, *Sparus macrocephalus* 41.4%; C(Zhang *et al*, 2010). However, lower values were previously reported for some omnivorous species, including, channel catfish, *Ictalurus punctatus* (28-32%) Robinson *et al* (2000), African catfish, *Clarias gariepinus* (34.4-39.9%) Farhat and Khan (2011) and the African bonytongue *Heterotis niloticus* (31.1%) Monentcham *et al* (2010). In their study, Adewolu and Benfey (2009) reported at least 35% dietary protein but did not confirm that as optimum protein requirement for the species because a growth plateau was not reached. There was a decrease in weight gain after a plateau is reached by fish when dietary protein levels get to and exceed their required values. Only a fraction of a surplus supply of protein in diets is used to synthesize protein (growth) and the remainder converted into energy according to Kpogue *et al* (2013). Jauncey (1981), also explained that growth rates decrease with protein levels higher than the optimum requirements since dietary energy accessible for growth reduces due to the energy necessary to determinate and excrete the excess amino acid absorbed.

The low growth obtained in this work for fish which fed on diets with CP levels beyond the estimated optimum inclusion level of 42.8% is possibly because a high portion of protein was utilize for maintenance making it unavailable for growth and the surplus broken down into amino acids which were later deaminated into carbohydrates.

Comparing the protein needs among fish species is complex by differences in species, size and age of fish, diet formulation, stocking density, protein quality, hygiene and experimental conditions between studies (NRC, 1993).

5.3.3 Feed Utilization

Feed utilization was best in fish fed the 40% protein diet. Fish receiving this feed had the highest protein intake. Feed conversion ratios have been shown to decrease with increasing dietary protein levels for a number of species, regardless of the conditions under which culture occurred. These include Mozambique tilapia (Juancey, 1982), African catfish (Degani *et al*, 1989) and claroteid catfish (Adewolu and Benfey, 2009). The high values of the FCR observed (3.2–6.48) corresponds to trends in the work of Adewolu and Benfey (2009) and can be attributed to the use of the easily accessible, cheap ingredients used in formulating diets. Higher FCR values have been recorded for a variety of species fed practical diets with locally available feed ingredients (Khan *et al*. 1993). Protein efficiency ratios conversely increased with increasing protein inclusion level with the best values recorded for fish fed on the estimated 40% inclusion diet contrasting with results from the work of Adewolu and Benfey (2009) which reported dietary protein level did not influence the PER except with 20%CP and explained that the trend shows that all other protein levels tested were efficiently used.

5.4 Feed Digestibility

Chemical analyses together with measuring digestibility are frequently engaged as an initial step in evaluating prospective feedstuffs according to Gaylord *et al* (2008). It is said that to efficiently assess feedstuff, digestibility is a priority. Asad *et al* (2008) explains that nutrient digestibility determination in feedstuffs is vital not only to aid in formulation of diets for maximized growth of fish that are cultured by the provision of needed quantities of available nutrients, but also to limit the wastes produced by the fish. Apparent Digestibility Coefficients (ADCs) of organic matter, protein and lipid increased along a parallel increase in protein content of the diets but was not significant for ADCs of protein and organic matter (Table 4.2). However, ADC of lipid increased significantly with increase in dietary protein level with the highest values (91.33%) recorded for 47.1% diets

Fish require lipids as a source of structural components of bio-membranes, for carrying fat-soluble vitamins, precursors to eicosanoids, hormones and vitamin D, and as enzyme co-factors (Lovell 1989). Some apparent lipid digestibility (ALD) coefficient ranges reported include 87.51% -104.16% (Pantazis and Neofitou, 2004) and 83.99% - 88.38% (Jimoh *et al*, 2014) in African catfish *Clarias gariepinus*. Conferring from Jimoh *et al*, (2014) a range of 76%- 97% lipid digestibility of variety fat sources have been documented for channel catfish. Compared to literature, results from this study is within the stated ranges for catfishes. Lipids are a preferred energy source for fish because they are highly digestible compared to carbohydrates and when lipids are adequately supplied in feeds, lower content of protein can possibly limit the capability of fish to maximally digest lipids compared to higher protein treatments (Mohanta *et al*. 2008; Ginindza, 2012).

The coefficient of organic matter digestibility stated in the current work appeared somewhat lower (64.57%-78.51) than the reported value in Pantazis and Neofitou, (2004) and as reported (75.92%-77.86) in Jimoh *et al*, (2014). Such variations according to Jimoh *et al,* (2014) may be ascribed to the methods of processing, and or methods used in the experiment. Gaylord and Gatlin (1996) explained that the digestibility of organic matter offers an overall estimate to what extent organic nutrients from the different ingredients are digestible. Organic matter digestibility is affected by the type of ingredients used. Higher inclusion levels of complex carbohydrates like starch and fibre, reduces the ability of the fish to digest the nutrients.

Fagbenro (1996) found various crude protein (58-92%) ADCs for animal and plantbased foodstuffs in *Clarias isheriensis* using chromic oxide as an indicator. Although the crude protein ADCs recorded in this experiment (70.59% -71.75%) fall within the stated range, it appears lower than records from Pantazis and Neofitou, (2004) (69.43%-92.88) and Jimoh *et al*, (2014) (88.06%-91.10%) for *Clarias gariepinus*. It is not clear why the apparent protein digestibility coefficient (APDC) recorded in this study for the formulated feeds were comparably low but this suggests the presence of factors that affected the Protein digestibility. It is however, acknowledged that nutrient digestibility is species specific (Jimoh *et al*, 2014)

5.5 Body Composition

Proximate composition according to Cui and Wootton (1988) is a good indicator of physiology needed for routine analysis of fisheries. Daniel (2015) illuminates the importance of information concerning the chemical composition of generally all freshwater fishes to nutritionists.

Results from this study show that the whole body composition of *C. nigrodigitatus* was influenced by the diets utilized in the experiment during the period of investigation

(Table 4.3). The whole-body protein correlated positively with the level of dietary protein. Whole-body lipid and ash also followed a similar trend up to 42.8% dietary protein and declined slightly at 47.1%. Percentage moisture negatively correlated with dietary protein level. Increase in the level of dietary protein significantly increased lipid contained in body composition ($P<0.05$). Work on the carcass composition of Nile tilapia produced similar results (Yang *et al*, 2002; El Saidy and Gaber, 2004 and Adewolu and Benfey, 2009). Generally, no consistent trends have been established in relation to effects of dietary protein levels on protein content of fish body according to Adewolu and Benfey (2009).

CHAPTER SIX

6.0 CONCLUSION

Based on the information gathered from interviews with selected fish farmers compared with existing literature on the life history and ecology of *Chrysichthys nigrodigitatus*, it can be concluded that knowledge on the biology and ecology of the current species is scanty. A few farmers have ventured into the culture of the species.

The farmers have limited knowledge on the culture of the species.

Information gathered on the species include;

a. *C. nigrodigitatus* is found in the Offin River in the Ashanti region.

b. Culture of the species has been tried under pond conditions and has yielded suitable results in the Region

c. The species is omnivorous and can be fed on compound feed

d. *C. nigrodigitatus* can grow to of about 0.6-1 kg in 6 months.

e. The fish spawn under culture conditions and the young survive under pond conditions.

Results of the nutritional studies suggests maximum growth of juvenile *C. nigrodigitatus* can be achieved with diet containing 42.8% dietary protein using fishmeal and soybean meals as the main protein sources.

7.0 RECOMMENDATION

The current study revealed the importance of *C. nigrodigitatus* as an alternative culture species in Ghana and the possibility of surviving under pond conditions with formulated diets.

It is recommended that the species should be fed diet containing 42.8% protein with fishmeal and soybean meal as the main protein sources. On-farm trial is suggested to monitor growth and survival since this study was conducted in tanks.

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