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DEPARTMENT OF FISHERIES AND WATERSHED MANAGEMENT
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THE POTENTIAL OF*HETEROTIS NILOTICUS* (AFRICAN BONY-TONGUE*)* AS AQUACULTURE CANDIDATE IN GHANA.

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DECLARATION

I hereby declare that this submission is my own work towards the M.Phil. Degree and that, to the best of my knowledge, it contains neither material previously published by another person nor material which has been 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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Certified by (Head of Department):

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Signature Date

DEDICATION

I dedicate this work to my wife Edith and twin daughters Isabel Sedinam and IsabellaSitsofe Akpaglo. Thank you very much for your patience and sacrifices throughout this work.

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ABSTRACT

Two studies were conducted on the African bony-tongue (*Heterotisniloticus)* a non-traditional farmed species in Ghana. The first study was done to assess indigenous and culture knowledge of fish farmers from the Ashanti and Eastern regions of Ghana on this non-traditional fish species. Subsequently, a nutritional study was conducted to determine the effect of varying dietary protein levels on the growth and feed utilization of the bony-tongue. The indigenous and culture knowledge of farmers on the bony-tongue were assessed by administering structured questionnaires to ten farmers; five from the Ashanti Region and five from the Eastern Region of Ghana. There is a growing interest of fish farmers for the culture of the bony-tongue. Therefore, there is the need for research to be conducted on this farmed fish species to enable research findings to be extended to farmers to enhance efficient farming of the bony tongue. The nutritional study evaluated the effect of four is oenergeticdiets with varying crude protein (CP) levels of 26.2%, 32.1%, 34.6% and 42.8% on growth; feed utilization and whole-body proximate composition of bony-tongue juveniles. *J*uveniles (initial weight: 32.65±0.03g) of the bony-tongue were stocked in rearing hapas (2x1m^2) at5 fish per hapa. Each diet was assigned to triplicate groups of fish in a completely randomized block design and the experiment lasted for ten weeks. An increasing growth trend and better feed utilization was observed as dietary protein levels increased from 26.2% to 42.8%. Fish fed 42.8% protein diet had the best growth performance and nutrient utilization, with a mean weight gain of 202.30±19.6%, feed conversion ratio of 1.20±0.15 and protein efficiency ratio of 1.66±0.2, however this was not significantly different from values of fish fed 32.1% and 34.6% dietary protein. Significantly lower values were recorded for fish fed 26.2% dietary protein. Whole- body nutrient composition of bony-tongue was not affected by the diets. The results of this study suggest that *H.niloticus* juveniles would grow best when fed diets containing at least 32.1% protein.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FUGURES

LIST OF PLATES

ACRONYMS

ANOVA:	Analysis of Variance
AOAC:	Association of Official Agricultural chemists
CF:	Crude Fibre
CL:	Crude Lipid
CP:	Crude Protein
CRD:	Completely Randomized Design
DAH:	Day after Hatching
DO:	Dissolved Oxygen
EAA:	Essential Amino Acid
FAO:	Food and Agriculture Organization
FBW:	Final Body Weight
FCR:	Feed Conversion Efficiency
FI:	Feed Intake
GDP:	Gross Domestic Product
IBW:	Initial Body Weight
K:	Condition Factor
MC:	Moisture Content
NRC:	National Research Council
PER:	Protein Efficiency Ratio
SGR:	Specific Growth Rate:
SSA:	Sub-Saharan Africa

CHAPTER ONE: INTRODUCTION

1.1 Background

Rivers in the tropics support extensive and intensive fisheries that provide the most important source of animal protein for people in many developing tropical countries (FAO, 2003). Rural people in Africa are particularly dependent on fish protein, and a great variety of species are harvested from river floodplain ecosystems (Welcomme, 2001). The largest fish are frequently targeted first and most intensively because they are generally more valuable. As larger fish become depleted, fisheries naturally shift effort towards successively smaller and less-valuable species (Welcomme, 2001). Fishery resources and aquatic habitats are negatively impacted by a rapidly increasing human population (Adite and Van Thielen, 1995).The world's human population continues to increase beyond 6 billion; however, its dependence on fish production as a cheaper source of protein has also increased (Chamberlain, 1993; Naylor *et al.*, 2000). Sustainable fisheries demand to meet the ever-increasing human population, require sufficient annual recruitment to balance population losses to harvest. Aquaculture is considered as a sustainable way of accelerating the recovery of the world fish stock through intensive production (Watson and Pauly, 2001).

In Ghana aquaculture has been adopted as an assured way of meeting the deficit in Ghana's fish requirements. According to the United Nations Food and Agriculture Organization (2005c), Ghana produced 51.7% of her requirements from its domestic sources and achieved 68.1% of national fish demand in 2004 through domestic productions and imports. Similarly Ghana's fish demand for 2007 was 913, 992 metric tonnes, however the country was able to supply only 511, 836 metric tonnes (Tradezone International, 2007) leaving a deficit of 402,156 metric tonnes.

Traditionally the main fish species farmed in Ghana is Nile tilapia (*Oreochromis niloticus*) which constitutes about 80% of aquaculture production and the catfishes (*Clarias species and Heterobranchusspecies*) accounts for the remaining 20 % (FAO, 2005c).

However, there are few indigenous fish species namely the African bony-tongue, *Heterotis niloticus*, claroteid catfish, *Chrysichthys nigrodigitatus* and the African snake head, *Parachanna obscura)*, which have aquaculture potential in Ghana (Dankwa *et., al*, 1999) but these species have not received extensive research attention. Nevertheless these non-traditional fish species are raised by farmers who buy fingerlings of these species from fishers who capture them from the wild and keep them in their aquaculture facilities such as ponds and concrete tanks.

Thus, gradually these species are becoming common species on selected fish farms. In spite of these bold initiatives by farmers to promote the farming of these non-indigenous fish species, there is little knowledge on the ecological, behavioural, natural feeding habitats including nutritional requirements as well as the reproduction of the species to inform both fisheries management and development of aquaculture technology (Adite *et al*., 2005) in Africa.

The African bony-tongue is one of the most highly valued food fish species in West African inland waters (Cuvier, 1829). This species is widely distributed in rivers and freshwater lakes of Western and Central Africa (Moreau 1982; Leveˆque *et al.*, 1990). Further more, the species supports an active capture fishers in inland water bodies in the

West African sub-region (Adite *et al*., 2005) including where it occurs in major rivers in the Volta basin mainly the White and Black Volta, Rivers Oti, Pra and Asukawkaw where the youngones are found in swampy places among aquatic vegetation (Dankwa *et al*.1999). It is an important food fish in Ghana with extensive aquaculture potential.

Some studies done on African bony-tongue include the biology, aquaculture performance (Aubenton 1955; Micha and Franck 1976; Adite *et al*. 2006), artificial reproduction in earthen ponds (Padi, 2006), the ecology (Moreau 1974; Moreau 1982; Adite *et al*.2005) of this species. Other studies include the ontogenetic, seasonal and spatial Variation in the diets of *Heterotis miloticus* (Adite *et al*.2005), population structure and reproduction (Adite *et al*., 2006), effect of weaning age on survival and growth (Adite *et al*., 2010) and influence of dietary protein level on growth performance and body composition of *Heterotis niloticus* fingerlings (Monentcham *et al*., 2009). The present study focused on the development of the African boney-tongue for culture in Ghana.

1.2 Justification

A need exist to identify new fish species that exhibits superior culture performance for use in improving the fish yield and diversifying aquaculture to reduce production risk. Progressively, studies in different parts of the world continue to investigate the use of "non-traditional" species in aquaculture ((USAID, 2005). In Ghana, as in many parts of sub-Saharan Africa, the tilapias and the clariid catfishes (*Clarias gariepinus* and *Heterobranchus sp*) have been the main focus of development effort in aquaculture for both subsistence and economic purposes largely because of their adaptability to culture environments (FAO, 2005c). Efforts in captive breeding have also contributed to the success of catfishes in aquaculture. However, there is a clear trend toward diversification at farmers' own initiatives in Ghana as some of these indigenous species including the *Heterotis niloticus, Parachanna obscura* and *Chrysichthys maurus are* seen on some farms. These species are highly valued food species in West African Inland fisheries (Dankwa *et al*., 1999). The African bony-tongue is considered one of these potential aquaculture species for development in Ghana (Dankwa *et al.*, 1999). The African bony-tongue is classified within the omnivorous fish category with a wide variety of food preferences (Fagade and Olaniyan, 1973, Lowe-McConnell, 1975, Lauzanne, 1976, Hickley andBayley, 1987). In captivity, remarkable growth performances of this species have been reported, with mean body weight of African bony-tongue reaching up to 3 to 4 kg in 12 months (Monentcham *et al*., 2009). The African bony-tongue is reported to have late sexual maturity, short food chain and reproduces naturally in ponds and possesses an important potential market, with a commercial value twice higher than that of tilapia qualifying it for aquaculture production (Monentcham *et al*., 2009).

However, information on the species is scanty and knowledge about their ecology and biology, especially their dietary requirements are still limited. Indigenous information given by farmers will therefore help researchers to have first-hand information about this species to enhance the research work on this species. Moreover, to consider the species for development in aquaculture, it is important to verify their life-history, trophic, and other ecological traits that could be exploited for commercial seed production and enhanced growth performance in culture facilities including ponds and cages. Documentation of such information will provide basis for further studies on the species for aquaculture development in Ghana.

1.3 Primary Objective

The primary objective of this research was to evaluate the potential of *Heterotis niloticus* as candidate fish species for aquaculture in Ghana bygathering information from literature and fish farmers and conducting experiments that could enhance knowledge on the nutritional requirements of African bony-tongue.

1.3.1 Specific Objectives;

- To assess farmers' indigenous knowledge of *Heterotis niloticus*.
- To evaluate the growth performance, feed utilization and whole-body composition of *H. niloticus* fed varying dietary protein levels.

1.4 Research Hypothesis

$H_{0:}$ Varying dietary protein level does not have effect on the growth rate of *H. nilocus.*

H_1:Varying dietary protein level does have effect on the growth rate of *H. nilocus.*

CHAPTER TWO: LITERATURE REVIEW

2.1Global State of Aquaculture

Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and providers of employment, income, and foreign exchange. About 950 million people worldwide, depend on fisheries and aquaculture, directly or indirectly, for their livelihoods (SPARE , 2003). Globally, the consumption of fish and fishery products as a protein source has increased considerably over the years constituting about 20% of total protein (FAO, 2006). The world population currently over 6 billion, and is predicted to exceed 8 billion by the year 2030, and consumption of sea food at that time is predicted to reach between 150-160 million tonnes (FAO, 2005b). Fisheries are also globally important source of employment for about 200 million people who depend directly upon ocean fishing for their livelihoods (FAO, 2006).

Preliminary estimates for 2005 based on reports from major fishing countries (China, South Korea, Russia, Iceland) indicate that total world fishery production reached almost 142 million tonnes, representing an increase of over 1 million tonnes compared with 200, a record high production (FAO, 2006). The increase in the catch per unit effort has resulted in fish resources from the ocean being classified as fully exploited, over-exploited or depleted (NRC, 1999). The high capacity fishing fleets using new technologies (freezer trawlers, radar and acoustic fish finders) and employing fishing strategies in fishing (Pauly *et al*., 2002). This will negatively impact fish stocks.

Fishing fleets continue to exhaust the ocean of fish stocks, as they continuously fish at lower trophic levels leading to an ecosystem susceptible to extensive damage

(Schiermeier, 2002). Analysis of fishing data by Myers and Worm (2003) indicates that with dominant fish populations declining, harvesting of alternative predatory fish species increased. This has necessitated a critical look at other areas such as aquaculture where fish could be produced to satisfy the demand for fish.

Aquaculture is defined as the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants (FAO, 1990). It covers activities within the main objective of producing freshwater, brackish and marine species under controlled or semi-controlled conditions. Aquaculture over the years has increased in many parts of the world to augment the shortage of fish from the wild from 5.3% in 1970 to 32.3% in 2000 (FAO, 2002).

The aquaculture industry continues to grow more rapidly than all other animal food-producing sectors in many countries of the world, with the world average annual growth rate for the world of 8.8 percent per year since 1970, compared with only 1.2 percent for capture fisheries and 2.8 percent for terrestrial farmed animal production systems (FAO, 2006). According to Chamberlain (1993), an annual growth of 6.5% is needed to meet the demand for seafood by the year 2025.

Aquaculture production in 2004 was reported to be 45.5 million tonnes with a value of US$63.3 billion. Total global fish production in 2005 was 157.53 million tonnes, of which aquaculture contributed about 40% (FAO, 2007). The average annual growth rate of the aquaculture sector during the period 1990 and 2004 was 9.4% per year. This has contributed significantly to food security and poverty alleviation in different parts of the world in parallel with the development of profit-oriented entrepreneurship (FAO, 2007).

Despite the significant growth of the aquaculture industry over the last two decades, it is faced with an increasing competition for primary resources such as land, water, feed and environmental concerns. As in other forms of animal husbandry, feeds and feeding are crucial elements in the culture of aquatic animals. The cost of feed is considered to be the highest recurrent cost in aquaculture, often ranging from 30-60% (De Silva and Anderson, 1995), depending on the intensity of the operation. The reduction in feed costs either through diet development is therefore crucial to the development and well-being of the industry.

Increased production of fish from aquaculture has occurred primarily as a result of increasing feed inputs into ponds and other production systems, thereby increasing yields per hectare by an order of magnitude compared to extensive production systems in which rearing water is fertilized only (SPARE Recommendations, 2003).

The effects of the aquaculture growth and changes in feed input in pond based culture have been dramatic with respect to the use of fish proteins. In the mid-1980s, less than 10% of annual fish meal production was used by the aquaculture sector. Today, that proportion is over 40% (Hardy and Tacon, 2002).

Estimates of future protein requirements for aquaculture feeds depend upon future production from various segments of the aquaculture industry and on annual production levels of fish meal. As aquaculture production expands, it will be essential to replace portions of fish meal and oil in fish feed formulations with alternative ingredients derived from other sources, primarily plant source products (SPARE Recommendations, 2003).

Environments and communities can benefit from aquaculture through the increase in the food supply, increase in employment, increase in food value, protection of aquatic biodiversity through restocking, reduction in need for wild catches and an improvement of fish habitats (Frankin and Hershner, 2003).

In spite of the benefits aquaculture has to offer, the production of aquaculture species may result in habitat destruction, contamination of waters through waste disposal, introduction of exotic species, pathogens, and the removal of large amounts of fish meal to meet their feed requirements (Naylor *et al.*, 2000). If aquaculture is to aid in the recovery of world fish stocks through intense production, it must exchange the "fishing down and farming up" strategy for a more sustainable approach (Watson and Pauly, 2001).

2.2 State of Aquaculture in Africa

African aquaculture currently contributes less than 1% of global production, with only larger-scale investments in Egypt, Ghana, Nigeria and Zimbabwe producing significant quantities of fish (FAO, 2005c). While African capture fisheries have been exploited to their maximum and aquaculture has languished, African demand for fish has grown. Compared to Asia, (with 25.7%) Africa ranks second (17.4%) with respect to importance of fish in the diet relative to total animal protein intake (Brummett, 2007).

Despite the increase in total fish supplies, fish consumption have not kept pace with population increase with Africa's consumption declining from an average of 9 kg (4.6 million tonnes total) in the early 1980's to 7.7 kg/yr (6.4 million tonnes total) currently (Brummett, 2007). In fifteen African countries, fish represents over 30% of animal protein consumption (FAO, 2005b).

Africa is home to a wide variety of indigenous and endemic species because of the continent's long and diverse geological history, and at least 3,200 freshwater species have been reported (FishBase, 2004).

2.3 State of Aquaculture in Ghana

Fisheries constitute an important sector in national economic development, and are estimated to contribute 3% of the total Gross Domestic Product (GDP) and 5% of the GDP in agriculture (Aggrey-Fynn, 2001) and is recognized as the most important source of animal protein (Aggrey-Fynn, 2001) providing about 60% of protein requirement of the population. In 2004 total production from fish farming was 950 tonnes, valued at ¢14.25 billion (US$ 1.5 million) (FAO, 2005c).

The national fish requirement has grown from 676 000 tonnes in 1995 to 840 000 tonnes in 2004, but production has not increased appreciably during the same period. The deficit between fish requirement and production was 400 000 tonnes in 2004 and has been the main driving force for pushing the agenda for developing aquaculture (FAO, 2005).

In Ghana, aquaculture has been regarded as a type of fishery and hence is included in other fishery legislation, lowering its value to the aquaculture sector. The Fisheries Act of 2002 (Act 625) is the main legislative instrument that governs the practice of aquaculture in Ghana.

Aquaculture has only recently been adopted as an assured way of meeting the deficit in Ghana's fish requirements. In 2003, Ghana produced only 51.7% of its requirements from its domestic sources and in 2004, achieved 68.1% of its fish requirement through domestic production and imports, thus there has been no appreciable increase in annual fish production over the years (FAO, 2005c). The aquaculture sector lacks the organization to take up the challenges of providing inputs such as fish seed and feed as viable commercial activities to support the development of the industry (FAO, 2004).

Suitable aquaculture sites are not concentrated but dispersed throughout the southern and middle belts of the country (FAO, 1991). Most of them depend on seepage of water from the pond bottom to fill the ponds. As a result the pond bottom cannot be dried fully before the next culture of fish, which adversely affects production. Some farmers depend solely on the natural productivity of the ponds to achieve their production and others use agricultural by-products to fertilize their ponds. Organic manure such as poultry droppings is also used (FAO, 2005).

2.3.1 Aquaculture Species in Ghana

Ghana's freshwater fish fauna includes 28 families, 73 genera and 157 species (Dankwa et., 1999) of these species, 121 have been recorded from the Volta river system (Ghana portion) which drains more than two-thirds of the country (Safo, 2007). The Volta system in Ghana includes the Volta River, the Volta Lake and their tributaries such as rivers Oti, Pra, White Volta, Black Volta and Asukawkaw. Outside the Volta system, the major inland water system includes the Densu, Ayensu, Okye, Kakum, Pra, Ankobra, Tano and Bia river basins and Lake Bosumtwi. Nine species, namely: *Barbus subinensis* (Cyprinidae), *Irvinea voltae* (Schilbeidae), *Chrysichthys walkeri* (Claroteidae), *Synodontis arnoulti*, *S. macrophthalmus*, *S.velifer* (Mochokidae), *Limbachromis robertsi*, *Steatocranus irvinea* (Cichlidae) and *Aethiomastacembelus praensis*

(Mastacembelidae) are endemic to freshwater systemsof Ghana (Dankwa et. al, 1999). The same author reported that, 81 species are economically, of food importance and the species of culture importance include: *Heterotis niloticus* (Osteoglossidae),*Clarias gariepinus, Heterobranchus longifilis* (Claridae), *Chrysichthys nigrodigitatus* (Claroteidae), *Oreochromis niloticus* (Cichlidae) and *Lates niloticus* (Centropomidae). Although a wide variety of fish have been tried in culture environments, the most common pond-raised fish in Ghana are tilapias (i.e. various fish from the genera *Oreochromis* and *Tilapia*) and catfishes (i.e. *Clarias, Heterobranchus* or their hybrid). Initially the catfish was a victim of the scarcity syndrome by requiring extraordinary hatchery techniques. It is however possible now to produce *Clarias* seed using farmer-friendly techniques on most farms (Safo, 2007).

2.4 Commercial Potential of African Bony-tongue (*Heterotis niloticus*)

In Benin, *H. niloticus* is an important fishery resource and is exploited intensively by both commercial and subsistence fishers (Adite *et al.*, 2005). It has been reported that annual capture of *H. niloticus* in Benin is estimated at 742tons with a commercial valued at US $1 485 000 (Benin Direction des Peˆches, Cotonou, 1996). According to Dankwa et al., (1999), *Heterotis niloticus* is of economic importance as a food fish and candidate for aquaculture Ghana. It possesses an important potential market, with a commercial value twice higher than that of tilapia. The rapid growth (3-4 kg in a 12-month cycle), late sexual maturity, short food chain and natural reproduction of this species in small and large ponds make it a good candidate for aquaculture production (Monentcham *et al.*, 2009).

2.4.1 Classification of African bony -tongue (*Heterotisniloticus)*

Heterotis niloticus is one of the two living representatives of the family Osteoglossidae, a lineage within the ancient fish order Osteoglossiformes, on the African continent (the other species is the fresh water butterfly fish, *Pantodon buchholtzi*). According to Guo-Qing and Wilson (1996), the Osteoglossidae also contains two genera and three species in South America and one genus and three species in Southeast Asia-East Indies-Australian region. According to Ferraris (2003), *H. niloticus* and *Arapaima gigas* (South America) are considered by many ichthyologists as the sole members of a separate family, the Arapaimatidae. Other living Osteoglossiformes include the Mormyridae (Africa), Gymnarchidae (Africa), and Notopteridae (Africa and Asia). Except for Pantondon (an egg scatterer), osteoglossids perform parental mouth-care brooding in *Osteoglossum* and *Scleropages spp*., and nest guarding in *Arapaima* and African bony-tongue.

2.4.2 Distribution of African bony-tongues (*Heterotis niloticus*)

All six of the known bony- tongue species inhabit tropical lowland rivers,lakes, and wetlands :(*Heterotis niloticus* (Cuvier,1829) in Africa;*Arapaima gigas* (Schinz, 1822) and *Osteoglossum spp*. in the Amazon Basin, and *Scleropages* spp. in Southeast Asia, the East Indies and North-eastern Australia (Greenwood1973, Moreau 1982, Li and Wilson 1996). *Heterotis niloticus*, the only species of bony tongue in Africa (Greenwood1973, Moreau 1982, Li and Wilson 1996), occurs in rivers of West Africa, the Nilo-Sudanian region and the Congo region of Central Africa (Aubenton 1955, Daget 1957, Leveque *et al*., 1990), and has been introduced in many lakes and aquaculture centres: Lake Kossou in Ivory Coast, Lake Nyong in Cameroon (Moreau 1974, Depierre and Vivien, 1977). In Ghana it is distributed in the Volta basin (Dankwa*et al*., 1999).

2.4.3 *Gender Determination and Gonad maturation*

According to Moreau (1982), gender is determined by macroscopical examination of gonads. Gonad maturation stages described by Amon-Kothias, (1980) in Adite *et al*., (2005) for *Heterotis niloticus* are as follows.

Female stages are:

i. Immature (juvenile) have very small gonad, ovary pink with oocytes invisible to naked eye.
ii. Early maturation is characterized by intermediate size ovary with very small pale yellow oocytes visible to naked eye.
iii. Advanced maturation is characterized by well developed ovary with yellow-orange (postvitellogenic) oocytes.
iv. Ripe ovary have fully developed, ovary fills ventral region of the abdominal cavity, eggs are post vitellogenic (diameter 2.5–3.0 mm) and expressed when external pressure is applied to the ventrum.
v. Post spawning is also characterized by ovary which is flaccid without significant presence of mature oocytes.

Male maturation stages are:

i. Immature (juvenile) –undeveloped testis consisting of a translucent filament.
ii. Early maturation – intermediate size testis having a very light yellow or tan colour.
iii. Advanced maturation– large testis, opaque white or light tan colour with numerous small, black spots.
iv. ripe testis – fully developed testis, pressure applied to ventrum expulses white milt;
v. post spawning–flaccid testis without milt.

Fish with gonads at stages 2–5 were considered sexually mature. The proportion of mature individuals increased rapidly between 550 and 800 mm, Standard length (SL) for both males and females. The size at which 50% of individuals were mature was about 575 mm, Total length (TL) for both genders. The smallest mature male (stage 2 gonad) was 560 mm TL (515 mm SL, 1.49 kg), and the smallest mature female (stage 2) was 545 mm TL (499 mm SL; 1.77 kg). The African bony tongue matures at 2 years (Moreau, 1982) and has relatively large eggs (2.5–3.0 mm) and moderate batch fecundity (2700–27,500) for a fish of its size.

Consequently, the species displays a life history strategy that is closer to the equilibrium endpoint than the periodic endpoint (Winemiller and Rose 1992), which implies that parental care is essential for early life stage survivorship and levels of recruitment needed for long term population viability (Van Winkle *et al*. 1993; Rose *et al*., 2001).

2.4.4 Nesting and Brooding

Studies on reproductive behaviour of the African boney-tongue have been investigated in the wild and also under artificial conditions in earthen ponds. Nests of *Heterotis niloticus* are circular clearings within dense stands of rooted and submerged or emergent aquatic macrophytes in shallow (<2 m) water (Adite *et al.,* 2005). Nests are highly conspicuous, even under moderately turbid water conditions (Secchi depth 0.5–1), due to the fact that rooted aquatic vegetation extends near or beyond the water surface. Each nest has a cleared channel through the vegetation that allows adult fish to pass between the confines of the nest and open water (Adite *et al.*, 2005).

Adite *et al.,* 2005 further noted that more than 85% of identifiable nests were active from April to October. In contrast Padi, (2006) who also investigated the reproductive behavoiur of the African boney-tongue observed spawning from March to October and stated that spawning occurred with increased temperatures and rainfall. Tending of nests and broods occur from the time of hatching until juveniles disperse from the nest (Adite *et al*, 2005).

2.4.5 Population Structure and Reproduction

Population structure of the African bony tongue, *Heterotis niloticus*, examined by Adite *et al*., (2005) in southern Benin within Lake Hlan and a region of the Soˆ River flood plain of which both locations support important fisheries in which *Heterotis niloticus* is the principal target species during the flood period, indicates that ripe adults comprised over 40% of the population in Lake Hlan, whereas only 3.5% of individuals captured from river sites were adults.

Monthly averages for the gonadosomatic index and percentages of individuals with mature gonads peaked as water levels increased during the wet season then declined during the peak flood period. Oocyte size frequency distributions from ovaries suggested a potential to produce an additional cohort in the event of nesting disruption. During the peak spawning period (May to August), between 37 and 51 active nests per hectare per month were observed in Lake Hlan. They further estimated the number of larvae per nest to range from 3953 to 6125.

2.4.6 Feeding Pattern

The African bony tongue has been characterized as microphagous (Lowe-McConnell, 1975, 1987) and feeding on variable amounts of plant material, including seeds, and benthic water column invertebrates (Lowe-McConnell, 1975; Lauzanne, 1976; Hickley and Bayley 1987). However, bony tongues from other tropical regions are piscivorous (*Arapaima gigas*) or are generalized carnivores that feed on fishes and a variety of terrestrial vertebrates and invertebrates (*Osteoglossum* and *Scleropages spp*.) (Goulding, 1980; Rainboth, 1996; Allen *et al.*, 2002).Some food items reported for *Heterotis niloticus* are indicated in Table 2.0

Table 2.1 Some suggested food source for *Heterotis niloticus*.

Food I	Food II	Food II	Food name	Country	Predator stage
Detritus	Detritus	Debris	Organic debris (<1mm)	Sudan	Juvenile/Adults
Detritus	Detritus	Debris	Organic debris (<1mm)	Sudan	Juvenile/Adults
Plants	Phytoplanktons	Blue-green algae	*Agmenellum sp*	Nigeria	Recruits/Juvenile
Zoobenthos	Mollusks	Gastropods	*Melanoides sp*.	Nigeria	Juvenile/Adults
Zoobenthos	Insects	Insects	not specified	Nigeria	Juvenile/Adults
Zoobenthos	Mollusks	Bivalves	not specified	Niger	Juvenile/Adults
Zooplankton	Other planktons	Other planktons	Unidentified	Ghana	Juvenile/Adults
Zooplankton	Plank. Crust	Planktons. Copepods	Unidentified	Ghana	Recruits/Juvenile

Source: www.fishbase.org(Accessed on 25th July 2010)

2.4.7 Seasonal variation in feeding

Variation in availability of food resources greatly affects fish feeding patterns over time and space, and such patterns often are particularly strong in systems with seasonal hydrological regimes where seasonal availability of marginal habitats and allochthonous resources may affect fish diets (Winemiller 1989, Ofori–Danson; 1992, Garcia-Berthou & Moreno-Amich, 2000; Winemiller and Kelso-Winemiller, 2003). In addition, ontogenetic diet shifts (size-related patterns of feeding) are a major feature of fish ecology (Winemiller 1989, Garcia-Berthou 1999, Garcia-Berthou and Moreno-Amich 2000; Claessen *et al*., 2002; Koen Alonso *et al*., 2002; Barbarino Duque and

Winemiller, 2003; Gill and Morgan, 2003). Larvae of most freshwater fishes consume tiny animals, especially microcrustacea and other forms of zooplankton, which yields relatively narrow diet breadth (Adriaens *et al.*, 2001). However as they grow, early fish life stages may ingest progressively larger and more diverse food items while maintaining or increasing feeding efficiency (Adriaens *et al.*, 2001; Steingrimsson and Gislason, 2002). Most detritivorous fishes develop morphological and behavioural adaptations that allow efficient ingestion, digestion, and assimilation of refractory organic matter in detritus (Bowen, 1983). The gizzard (muscular, thick-walled pyloric stomach) and pyloric caecae (blind pouches) of the gut of *H. niloticus* are examples of such adaptations (Moreau, 1982).

2.5 Nutritional Requirements of Fish

According to Moyle and Cech (1982), there are four main constituents in the diet of fish; proteins, carbohydrates, lipids (fats) and vitamins which are important for both growth (anabolism) and as an energy source (catabolism). Fish nutrition has in recent years advanced with the development of new, balanced commercial diets that enhance optimal fish growth and health (Kaushik, 2000). Tilapias are omnivorous and capable of producing high quality protein from less refined protein sources thus making them ecologically attractive as sources of animal protein for humans (Jauncey, 1998). According to Popma and Masser(1999), the genus *Oreochromis* generally feed on algae, aquatic plants, small invertebrates, detrital material and associated bacterial films. *Oreochromis* are considered opportunistic and this gives an advantage to farmers as the fish can be reared in extensive situations that depend upon the natural productivity of a water body or in intensive systems that can be operated with lower cost feeds (Fitzsimmons, 1997). *Heterotis niloticus* is also classified in the omnivorous fish category but no extensive research has been done on its nutrients requirements (Micha 1976; Adite et al. 2005).The best growth performance of tilapia is exhibited when they are fed abalanced diet that provides a proper balance of protein, carbohydrates, lipids, vitamins, minerals and fibre. Nutritional requirements of fish differ for different species and more importantly vary with life stage. Fry and fingerlings require diets with higher protein, lipids, vitamins and minerals and lower carbohydrates as they are developing muscle, internal organs and bones with rapid growth (Fitzsimmons, 1997). Studies have shown that the protein requirements of juvenile tilapia range between 30-56% (Jauncey, 1998; Suresh, 2003). The protein requirements of fish decrease withage. There are limited and inconsistent data on the essential amino acid (EAA) requirements of fish (Suresh, 2003). Dietary lipid levels for tilapias in general are reported to range from 5% to 12% (Suresh, 2003). Fitzsimmons, (1997) recommended that dietary lipids contain both omega -3 and omega- 6 fatty acids each representing 1% of the diet, although some reports suggest that fish grow better with a higher proportion of omega- 6 to omega- 3. Older fishes are reported to cope with higher dietary fibre content with a maximum range of 8-10% compared to younger ones which require 6-8%of fibre (Jauncey: 1998, Fitzsimmons, 1997). Shiau (1997) reported that carbohydrates usually represent less than25% of the diet for fish that are less than 1.0g and this increases to 25 - 30% for fish greater than 1.0g till harvest. Minerals and vitamins are considered essential for good and balanced nutrition in tilapia and a number of studies have been done to ascertain these requirements (El-Sayed and Teshima, 1991; Jauncey and Ross, 1982; Roem *et al*., 1990; Watanabe *et al*., 1997).Biological factors such as the size, age, condition, and reproductive state of the fish (Riche and Garling, 2003) and a biotic factors such as temperature, dissolved oxygen, water quality, and photoperiod also affect nutrient requirements. The feeding management (amount, and frequency of feeding), the diet itself, thus amount and quality of protein, energy, and the method of processing will also affect its requirements. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for the optimal growth and health of the fish and are used in systems that cannot provide any dependable nutrition (Fitzsimmons, 1997).

2.5.1 Protein as a Major Feed Nutrient

According to Jobling (1994), Proteins are composed of carbon (50-55%), nitrogen (15-18%), oxygen (21-23%), hydrogen (6-8%) and sulphur (0-4%). Protein levels in aquaculture feeds generally average 18-20% for marine shrimp, 28-32% for catfish, 32-38% for tilapia, and 38-42% for hybrid striped bass (Craig and Helfrich, 2004). Protein requirements usually are lower for herbivorous fish (plant eating) and omnivorous fish (plant-animal eaters) than they are for carnivorous (flesh-eating) fish, and are higher for fish reared in high density (recirculating aquaculture) than low density (pond aquaculture) systems.

The energy requirements of fish are lower hence the higher protein requirements for fish (Smith, 1989). According to NRC(1993), the ratio of digestible protein to energy required for optimal fish growth ranges from 81-117 mg $kcal^{-1}$ (NRC, 1993) which is significantly higher than for pigs and broiler chickens which range from 40-60 mg $kcal^{-1}$

(NRC, 1993). When energy is in excess, fish may reduce feed intake thereby limiting the intake of amino acids needed for growth, while deficient energy leads to the utilization of protein for maintenance instead of growth.

Protein requirements generally are higher for smaller fish but decreases as the fish grows larger (Stickney, 1986; Rakocy and McGinty, 1989). Protein requirements also vary with rearing environment, water temperature and water quality, as well as the genetic composition and feeding rates of the fish. Dietary protein requirements has been studied in a number of fish species (NRC 1993), but no reports on protein requirements so far on *H. niloticus* till Monentcham et al., (2009), researched on protein requirement of *H. niloticus* fingerlings. Using the broken line model of Robbins et al. (1979), they estimated the dietary protein requirement for *Heterotis niloticus* fingerlings (26–62 g) based on percentage WG to be 311g protein kg^{-1} diet.

2.5.2 Dietary Protein Requirement Studies in Fish

Protein requirements, implies the minimum amount needed to meet requirements for amino acids and to achieve maximum growth. This is generally measured in juvenile fish of many species obtained mainly from dose response curves in which graded amounts of high- quality proteins were fed in partially defined diets. Weight gain was the response measured and the values expressed as a percentage of dry weight. The method used to determine protein requirements however, may overestimate requirements, in that excess dietary protein or amino acid, which cannot be stored, are catabolized preferentially over carbohydrates and fats and used for energy by some fishes (Wilson, 1989). Moreover, adequate consideration has not always been given to factors such as concentration of digestible energy in the diet, amino acid composition of the dietary protein, and digestibility of the dietary protein (Wilson and Halver, 1986; Wilson, 1989).

Page and Andrews (1973) reported that 25% protein was adequate in the diet of channel catfish of 114g to500g, but 35% produced faster gain than did 25% protein in 14-100g fish. Wilson and Halver (1986) also reported somewhat similar result for salmonids, common carp and tilapia. According to the NRC, (1981, 1983), linear relationship exist between amino acid requirement and protein intake, and on this basis amino acid requirement of fish were expressed as the a percentage of dietary protein as well as on dry matter basis. Finke et al (1987) however, saw the relationship between amino acid requirement and protein intake to be exponential. Thus, the broken-line analysis was used to assess protein requirement of fish on a dose-response curve. Moreover, Finke et al (1989) employed the use of a logistic model as a more accurate assessment than that provided by broken-line analysis of the diminishing returns area of the response curve and of the maximum return. According to Gahl et.al (1991), the linear relationship (dose-response relationship) is for all practical purposes.

2.5.3 Larval Mortality of *Heterotis niloticus*

The success of a fish species in aquaculture depends on the production and the availability of fingerlings to supply fish culture centres (FAO, 1991; Egna and Boyd, 1997; Rønnestad *et al*., 2001; Adite *et al*., 2005, 2006; Monentcham, 2009). Rearing of fish larvae however, has been deemed a major concern for many aquaculture processes (El-Dakar *et al*., 2001). High larval mortality occurs during the weaning phase in some major species because of poor food digestion resulting from a less-developed and rudimentary larval digestive tract (Watanabe and Kiron 1994; Breine et *al.,* 1995; Rønnestad *et al*., 2001). *Heterotis niloticus* like many fish species, larvae exhibit a very high mortality rate ranging between 80%and 100% (Moreau, 1982). Indeed, in fish ponds, at 50 days after hatching (DAH) and 90 DAH, De Kimpe (1967) and Rakotomanampisson (1966) reported some mortality rates of about 82% and 96% respectively. According to Reizer (1964, 1968) and Vincke (1971) a mortality rate of 100% usually occurs between 5 DAH and 7 DAH and the whole school of *Heterotis* larvae could disappear in a short time (Daget and Aubenton, 1956; Rakotomanampisson, 1966). Daget (1957) hypothesized that the massive mortality occurs after the weaning phase because of the food change. Once the larvae are weaned, only bigger individual continue to swim to search for food whereas weaker individuals swim less, fall in the bottom before dying (Rakotomanampisson, 1966). Monentcham (2009) indicated that protein contents of the artificial food may affect the survival and growth performance of *H. niloticus* larvae and juvenile. In addition to the high food requirement for rapid growth, Micha (1973) reported that high larval density reduces rapid food consumption of individual larvae. The combined effects of these causes could act to increase the mortality of *Heterotis niloticus* larvae (Moreau, 1982).

2.6 General Feed Situationsin Aquaculture

Fish nutritionist all over the world are constantly searching for the dietary protein sources in which fish will maximize growth and increase production within the shortest possible time and at lowest cost (Kaushik, 2000). According to FAO (2007), feeds and fertilizers will continue to dominate aquaculture needs. The importance of feed in aquaculture is emphasized by the fact that about 28.2 million tones (44.8%) of total global aquaculture products in 2005 was dependent on single dietary ingredients, farm-made aqua feeds and industrially manufactured aqua feeds.

Traditionally, feeds eaten by monogastric farm animals (animals with simple single chambered stomachs) are believed to be suitable for feeding fish (Ling, 1967; Hastings, 1975; Fowler and Banks, 1976a, 1976b; Randall, 1977). These materials include the feed grains, oilcake and meals, animal by-products (including fish meal), and an assortment of industrial and agricultural waste products. Most of these, however, have not been properly evaluated as fish feed.

Barnabé (1994) reported that aquaculture feeds are designated as dry, moist or paste. The diets can be given to fish in the form of pellets, cakes and powder. The main objectives in diet formulation for aquaculture are to: (a) satisfy all known nutrient requirements for growth of the species; (b) minimize feed cost; and (c) select and use ingredients that will result in products that are readily utilized to minimize wastage (FAO, 1983). There is currently great interest within the animal feed industry to reduce costs by using locally available feed ingredients. The need to increase aquaculture production requires corresponding increases in nutrition related inputs; i.e. intensifying culture practices by feeding more and better feedstuffs (Machena and Moehl, 2001). Feeds are mostly based on agricultural by-products available in an area and may be of modest quality but of a reliable quantity. Commercially produced feeds require cost-effective inputs and the industrial means to manufacture feeds, preferably pelletized feeds. Therefore, countries that have expanding agricultural sectors and produce surpluses are often well placed for the economical production of commercial fish feeds (Machena and Moehl, 2001).According to Moehl and Halwart (2005) reliance on farm-made products to satisfy feed requirements of aquaculture organisms is prevalent in all the Sub-Saharan African (SSA) countries. A formal aqua feed manufacturing sector is now being developed in Ghana. Feeds are still mostly produced at the farm level and inmost cases only one, or a mixture of two or more feed ingredients. Hecht (2007) reported that farm-made feeds were estimated to be 547mt and feeds produced on a small pilot scale at 2 mt per month. Ghana is reported to have adequate oilseed cake resources to supply present requirements and for future demand by aquaculture (Abban, 2005). According to Hecht (2007), carbohydrate sources, (rice bran, maize bran and wheat bran) are the resources readily available. Rice and maize production in Ghana in 2005 was 241,807 mt and 1,157,621 mt respectively and the total production of cereals in the same year amounted to 1,943,000mt (FAO, 2006). In Ghana presently fish meal, which is the main protein source, is in short supply as demand by the livestock and poultry industry is high. However, oilseed by-products substituted for fish meal are available in Ghana the most important being groundnuts, cottonseed, soybean, copra and palm kernel among others. Groundnut production in Ghana has increased since 1961 from 47,000 mt to 520,000 mt in 2003 making it the ninth largest producer in the world (World Geography of the peanut, 2004). Groundnut cake is used as human food; however, industrially produced cake is sold for animal feed (Agyenim-Boateng *et al.*, 1990).According to Clark (1994), cotton production in Ghana expanded rapidly from 4% of the country's national requirement in 1970 to 50% in 1990. Thehighest it achieved was 24,000 mt in 1998 and 24, 244 mt in 2003 (Ghanaian, Migrant Information Service, 2008). Hecht, (2007), reported that despite the low production of cottonseed meal in Ghana it is readily available at cheap prices. The most commonly and readily available plant product used as a protein source in Sub-Saharan Africa is soybean meal, which is generally imported (Hecht, 2007).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Ashanti and Eastern Regions of Ghana from February 2010 to2011 February. The first part of the research focused on the assessment of the indigenous culture and knowledge of culture practices and the biology of the boney-tongue by wild capture fishers and fish farmers in the Ashanti and Eastern Regions of Ghana. The second study, involved nutritional studies, i.e. protein requirement studies, which was carried out at the premises of the Data Stream Hatchery at Old Akrade in the Asuogyaman District of the Eastern Region of Ghana. The Data Stream Hatchery is well equipped with modern facilities e.g. aerators, ultra violet clarifier, water quality apparatus and large concrete tanks to carry out the experiment. This farm is located close to bank of the Volta River and therefore has easy access to freshwater.

3.2 Assessment of Culture and Indigenous Knowledge of *Heterotis niloticus*

A survey to assess the culture and indigenous knowledge of *Heterotis niloticus* was carried out through the administration of structured questionnaires (Appendix 1) to 5 fish farmers from the Ashanti and 5 from the Eastern Regions of Ghana. The selection of the farmers was based on purposive sampling targeting only fish farmers who were culturing *Heterotis niloticus* either in a monoculture or polyculture. The farmers were given structured questionnaires to fill.

The survey was aimed at obtaining first-hand general information on the culture, biology and the nutrition of this species from farmers for use by researchers to develop

Heterotis niloticus and the host of other non-traditional species of aquaculture importance in Ghana.

3.3 Experimental Facility for the Nutritional Study

The Nutritional study was carried out at premises of Data stream Hatchery at Old Akrade in the Eastern Region of Ghana. Twelve hapas ($2x1m^2$) mounted in a concrete tank ($5x20m^2$) were used for the feed trial. Before mounting hapas, the concrete tank was cleaned with Agricultural lime (calcium carbonate) applied at about 3 kg to the tank to kill bacteria and other micro-organisms and was left to dry for about a week. The tank was later filled with water pumped from the Volta River since the farm is located at the bank of the river. The concrete tank located under a shed was fitted with an air blower for water aeration and ultra violet clarifier for water disinfection.

Plate 1 Hapas mounted in a concrete tank that was used for the feed trial on the boney-tongue (*Heterotis niloticus*).

3.4 Experimental Ingredients, Diets formulation and Preparation.

All ingredients were obtained locally from the market. Four isoenergetic diets were formulated to contain varying crude protein levels of 26.2%, 32.1%, 34.6% and 42.8%. Fish meal and soybean meal were used as the main protein sources in the ratio of 2:1 while rice bran and wheat bran were used as energy sources (Table 3.1). A vitamin and mineral premix were used and cassava flour was used as a binder. Palm oil was used as a source of lipid in the diets. All ingredients were ground into powdery form using a milling machine. The feedstuffs were weighed and thoroughly mixed with hand to obtain a homogenous mixture. Warm water was added (20-30%) to the mixture and mixed thoroughly to get a homogenous mixture. The diets were then pelletized using an electric mincer (Moulinex Mincer HV6, France) which extruded the wet feed out through a 2mm diameter die. The wet pellets were then oven dried at a temperature of 60^{o}C for 24 hours until water content reduced and stored in airtight containers throughout the experimental period.

Table 3.1 Composition of experimental diets (% as-fed) fed to *Heterotis niloticus* with varying inclusion levels of crude protein (CP)

Ingredients	26.2%CP (Diet 1)	32.1%CP (Diet 2)	34.6%CP (Diet 3)	42.8%CP (Diet 4)
Fishmeal	18.0	23.7	29.8	35.0
Soybean meal	14.0	18.8	22.2	27.0
Rice bran	38.0	30.5	23.0	15.0
Wheat bran	18.6	15.5	13.5	11.0
Salt	1.0	1.0	1.0	1.0
Palm oil	2.0	2.0	2.0	2.0
Diphosphate	2.0	2.0	2.0	2.0
Cassava flour	2.5	2.5	2.5	2.5
Vitamin and Mineral premix*	4.0	4.0	4.0	4.0
Total	100.0	100.0	100.0	100.0

**Contained (as mg kg^{-1} of diet):Vitamin A (I.U), 320,000; Vitamin D3 (I.U), 60,000; Vitamin E, 100;Vitamin K3, 40; Vitamin B2, 80; Vitamin B12, 0.05; Folic Acid, 20; Nicotinic Acid(mg), 320; Calcium panthotenate, 80; Choline cloruro, 2000; Sulphate mangnesium, 2000; Zinc oxide,1600; Penta-hygrate sulphate copper, 180; Hepta-hydrate sulphate cobalt,4; Potassium iodine, 40; Sodium selenium, 4; Butylated hydroxytoluene, 400 (Manufactured by DEX IBERICA, S.A. NUTRIDEX LAYER PREMIX®, Premixture)*

3.5 Water Quality

During the experimental period, mean water temperature and dissolved oxygen (DO) concentration were measured daily at a depth of5 cm below the water surface using a WTM, OxiCal-SL portable electronic probe. Other water quality parameters such as pH was measured with Suntex model SP-701 pH meter and ammonia was also measured at 5-day intervals using methods described by Allan *et al*, (1990).

Table 3.2. Water quality parameters in experimental units (Hapas) over 70 day's period

Treatment	Temperature (^{O}C)	Dissolve Oxygen (mg l^{-1})	pH	Ammonia (mg l^{-1})
26.2 %CP	27.14 ± 0.157	4.018 ± 0.018	6.55 ±0.043	0.0016 ± 0.0002
32.1 % CP	26.46 ± 0.200	4.273 ± 0.195	6.42 ± 0.072	0.0017 ± 0.0002
34.6 % CP	26.72 ± 0.181	4.018 ± 0.186	6.36 ± 0.058	0.0017 ± 0.0002
42.8 % CP	27.24 ± 0.128	4.109 ± 0.110	± 0.043	0.09±0.0002

3.6 Experimental Fish, Acclimatization, Stocking and Feeding

A total of sixty fingerlings of *H. niloticus* (mean weight of 32.7 ± 0.20 g) obtained from a fisherman from Kpong in the Eastern Region, were used for the study. These fish were caught from the wild and kept in hapas mounted in a concrete tank. The fish were allowed to acclimatize for two weeks prior to the start of the feed trial. During this period, the fish were fed on (crumbles) imported feed with 45% crude protein (Raanan feed from Israel). The fish were randomly distributed at stocking density of 5fish per hapa (2m^{2}) into 12 experimental hapas (four treatments with three replicates) after the acclimatization period and were hand-fed to satiation with the four formulated (experimental) diets with crude protein 26.17,32.08,34.61 and 42.81%, twice daily at 0700h and 1600h during the feed trial.

Plate 2: Sample of theAfrican bony -tongue (*Heterotis niloticus*) used in theexperiment

3.7 Chemical Analyses

Proximate compositions (moisture, crude protein, crude lipid, crude fibre, and ash) and gross energy of experimental ingredients, diets and fish body composition were analysed before and after the trials were carried out at the Department of Fisheries and Watershed Management, Department of Bio-chemistry and Food science Technology laboratories of KNUST. The proximate analysis was in accordance with standard methods of the Association of Official Agricultural Chemists (1990). All the chemical analyses were done in triplicates.

3.7.1 Moisture Content Determination

Moisture content (MC) was determined by air-drying approximately 5.0g sample in an oven (Gallenkamp Hotbox Oven with fan size 1) thermostatically controlled at 110^{0}C for 12 hours. The samples were removed from the oven and the dish was placed in a desiccator to cool before weighing. Report on the loss in initial and final weight of sample is a gravimetric measurement of water in the dietary ingredients, diets expressed as a percentage of the initial sample weight.

$$\text{Moisture\%} = \frac{(Initial\ weight - Final\ weight)}{Initial\ weight} \times 100$$

3.7.2 Ash Content Determination

Ash (measurement of the total inorganic matter) was determined by incinerating approximately 2.00g of sample put into a pre-weighed crucible and placed in a Stuart Scientific Muffle furnace at 550^{0}C overnight. The change in the final and initial weight of empty crucible and crucible containing the sample after incineration represented the ash. It was expressed as percentage of the original sample.

$$\text{Ash content (\%)} = \frac{\text{(Weight of ash)}}{\text{(Weight of sample)}} \text{ x 100 (AOAC, 1990)}$$

3.7.3 Crude Protein Determination

Kjeldahl method was used for the determination of crude protein (CP). Approximately 2.00g sample was digested in 25ml concentrated sulphuric acid with a selenium based catalyst tablet (contains 3.5g potassium sulphate and 3.5mg Selenium). The sample was digested in a Tecator instrument digester. 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.

Nitrogen content was calculated by:

$$N(\%) = \frac{0.7\,(V_1 - V_0)}{M} \quad \text{(AOAC, 1990)}$$

Where V_1 is the mean volume in ml of 0·1 M hydrochloric acid required for sample,

V_0 is the mean volume in ml of 0·1 M hydrochloric acid required for blank, and

M is the weight in grams of the portion taken of the sample.

Percentage nitrogen was finally converted to crude protein by multiplying by 6·25.

3.7.4 Crude Lipid Determination

The method employed was that of solvent extraction using Soxhlet extraction apparatus. Approximately 2.00g of dried sample was weighed into 22x80mm thimble. Petroleum-ether 40-60^0 C (contains approximately 2% n-Hexane) was added to a pre-weighed flask. The thimbles were placed into the unit. A condenser with three glass balls was connected to the soxhlet extractor and reflux for 16 hours on low heat setting with Thermo Scientific mantle (Scientific Laboratory Supplies, UK) at a condensation rate of 2 to 3 drops per second. The flask and fat were heated for 30minutes in an oven at 103^{0}C before weighing to determine the weight of the fat, expressed as a percentage of the original sample. Extraction which involved boiling, rinsing and evaporation was conducted following the instructions in the manufacturers' manual.

3.7.5 Crude Fibre Determination

Crude fibre was determimed by the AOAC,(1990) standard method. Approximately 2.00g 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 550^0C and crude fibre in the defatted sample expressed as a percentage of the original undefatted sample.

$$C_{fibre} = \frac{(b - c)}{a} \times 100$$ (AOAC, 1990)

Where:

a is the mass (g) of the sample.

b is the loss of mass (g) after ashing during the determination;

c is the loss of mass (g) after ashing during the blank test.

3.7.6 Nitrogen- Free Extracts

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

3.7.7 Gross Energy Analysis

Gross energy was calculated after NRC (1993) as 23.6, 39.5 and 17.2 $Kj.g^{-1}$for protein, lipid and carbohydrate respectively.

3.8 Weighing Procedures, Data Collection and Analysis

Fish were individually picked with a scoop net from the hapas and gently blotted on a soft paper towel (in an attempt to reduce errors of fish weights recorded due to water adhering to each fish body) before they were bulk weighed on an electric scale (Sartorius BP 4100, AG Gottingen, Germany) to the nearest 0.01g. The frequency of sampling was every 7 days for a period of 10 weeks. The Standard Length was determined with a measuring board. The experimental hapas were inspected daily to remove dead fish, if any. The feed intake was determined weekly by subtracting the weight of feed given from the initial weight of feed. Fish weight gain, feed conversion ratio, specific growth rate and survival were determined as follows. The mean weights per treatment in each hapa were computed as follows:

(i) Weight Gain

Weight Gain (WG) was determined as the difference between the final body weight and the initial body weight of fish over a period of time. It was calculated as:

$$WG\ (\%) = \frac{\text{Final Weight of fish} - \text{Initial Weight of fish}}{\text{Initial Weight of fish}} \times 100 \qquad (1)$$

(ii) Specific growth rate

Specific growth rate (SGR) is the instantaneous change in weight of fish expressed as the percentage increase in body weight per day over any given time interval and expresses growth as $\%.day^{-1}$ as described by Ricker (1979). It was calculated as:

$$SGR\ (\%\ per\ day) = (Log_e W_2 - Log_e W_1)/(T_2 - T_1) \times 100 \quad (2)$$

Where: W2 = Weight of fish at time T_2 (final), W1 = Weight of fish at time T_1 (initial)

(iii) Feed conversion ratio

Feed conversion ratio (FCR) was calculated from the relationship of feed intake and wet weight gain.

FCR = Total feed given to fish (g) /Weight gained by fish (g)(3)

(iv) Condition Factor

Condition factor (K) was calculated as: $K = (BW / SL^3) \times 100$. Where BW = mean body weight of fish (g), SL = mean standard length of fish (cm). (4)

(v) Survival

Survival was calculated as:

Survival (%) = (Final Number of fish/Initial Number of fish stocked) X 100 (5)

(vi) Protein Efficiency Ratio

Protein Efficiency Ratio (PER) is defined as the ratio between the weight gain of fish and the amount of protein fed (De Silva and Anderson, 1995). It was calculated as:

PER = Weight gained (g)/Crude Protein fed (g) (6)

Body Composition of Fish

At the end of the culture period two samples of fish were randomly selected from each of the experimental hapas to determine whole body composition of the fish. The proximate analysis followed methods described in Section3.6 and components such as moisture, crude protein, crude lipid and ash were analysed and expressed as percentage of fresh weight.

3.10 Statistical Analysis

The experimental design used was mainly Completely Randomized Design (CRD) where different dietary treatments were randomly assigned to the experimental units (hapas). Data from the research was subjected to one-way analysis of variance (ANOVA) followed by the Tukey's multiple comparison test for the means at a significance level ($p>0.05$). The statistical package used for the analysis was Graph Pad InStat tm. Results were presented as mean ±SE (standard Error). All percentages were arcsine transformed before analysis (Zar, 1984). The collected from the survey analysed using SPSS software and the results expressed as percentages.

CHAPTER FOUR: RESULTS

4.1 Assessment of Culture and indigenous Knowledge of African bony-tongue (*Heterotis niloticus*).

Results from the survey of indigenous knowledge of *Heterotisniloticus* are presented as follows:

4.1.1 Training and fish farming experience by farmers

The ages of all the fish farmers who culture *Heterotis niloticus* ranged 49 to 63 years. In all, 50 % (5 farmers) had secondary education and the remaining five farmers had tertiary education. Thirty percent (30%) of the farmers are professionals and practiced fish farming as part time job. The remaining farmers who comprised 70% of the respondents practiced fish farming as a full time occupation. Majority (80%) of the farmers had training in fish farming either through seminars or short courses from Agricultural schools in Ghana. Onlyfew (20%) fish farmers had no formal training in fish farming.

The least experienced farmers who constituted 30% of the farmers surveyed have been in fish farming for less than one year to a maximum of 5 years. Fifty percent (50%) of the farmers hadbetween 5 to 10 years of fish farming experience whereas the highly experienced farmers (>10 years) comprised only 20% of respondents surveyed in this present study.

4.1.2 Polyculture of H. niloticus with Tilapia and Catfish

All the fish farmers interviewed were engaged in the culture of *H. niloticus*. Seventy five percent (75%) of the fish farmers culture *H. niloticus*, Nile tilapia (*Oreochromis niloticus)* and African catfish (*Clarias gariepinus*) in a polyculture. Few farmers (20%) integrated *H. niloticus* with livestock and crops: piggery (Plate 3) or rice crop (Plate 4)

Plate 3 piggery

Plate 4 Rice cultivated in an empty pond

4.1.3Heterotis niloticus Production

4.1.3.1 Ponds and Water quality

Earthen ponds were used by farmers in culturing *H. niloticus*. These ponds receive water from river (20%), groundwater (50%) and rain (30%). Twenty percent (20%) of farmers had irregular water supply for raising fish in their ponds whereas majority (80%) of farmers had water constantly flowing through their ponds. Majority (70%) of the farmers surveyed had ponds ranging from 1 to 10 hectares (ha) whereas only few (30%) had very large ponds totaling more than 10 hectares. Majority (80%) farmers used loamy soil for such pond construction and the remainder (20%) of farmers used clayey soil. Few (20%) of the fish farmers had no vegetation (Plate 5) in the ponds. In contrast 80% of the farmers had vegetation in their ponds (Plate 6)

Plate 5: Pond devoid of aquatic vegetation but with underground water source for raising fish.

Plate 6 Nest constructed by *Heterotis niloticus* using aquatic weeds inside a fish pond.

4.1.3.2. Stocking and Fish Performance

Eighty percent (80%) of the farmers mainly capture their *H. niloticus* stock (brood stock or fingerling) from the wild especially from Offin River. However, 20% of the farmers depend on other commercial fish farms such as Kuma Farms Limited at Awomaso, Kumasi in Ashanti Region for their supply. The average distance covered by farmers from their farms to the source of *H. niloticus* acquisition was noted to be between 6 and 25 km. Majority of the farmers stock the fish at size ranging from 5g to 500g but other farmers did not note the sizes they stocked. It was however clear from the farmers that the sizes stocked depend on the sizes they got from fishermen from the wild, which also depends on the siene net used. The size of fish caught in seine nets increased with increased mesh size of the net. This suggests fish of mixed ages were stocked. A few (25%) farmers stocked fish at 156 to approximately 1000 individual fish per pond (average pond size was approximately 1250m^2) whereas majority (75%) had no knowledge about the stocking rate. The stocking rates given by these farmers are based on the availability of the fish but not based on any known stocking rates. Most of the farmers had their stock from the wild (River Offin) and a few (25%) had theirs from other farms. The fish caught from the wild had no definite weight at stocking since this depends on the size of the fish trapped. However, those who had their stock from other farms stocked at fingerling stages at more uniform sizes as compared to those from the wild. In most cases, farmers did not take into consideration the size of the pond. Moreover, farmers stocked fish in ponds devoid of predators preventing mortalities through predation. However, a few farmers lost their stock owing to stocking in ponds containing predatory fish and stocking at smaller sizes.

4.1.3.3. Ecological Niche

Farmers reported that they saw both adult and juvenile *H. niloticus* frequenting the vegetated parts of their ponds. Few farmers (30%) had no idea where the fish could be found in any particular section of their ponds. Sometimes the fish were spotted by famers feeding on insects and tinny seeds floating on the surface of the pond. Farmers reported observing juvenile fish mostly in the rainy season in the Ashanti and Eastern Regions of Ghana. Rainfall and presence of vegetation were some of the conditions stated by farmers to induce spawning; however, 20% of the farmers had no idea of factors that contribute to spawning in *H.niloticus*.

4.1.3.4.Feeding

All the farmers observed the fish feeding on some plants and insect related organisms in the ponds such as algae, termites and even cabbage. Fifty percent (50%) of the farmers use compounded feed as supplementary feed while 50% never fed with compounded feed before because of the presence of green algae in the ponds. Those who use compounded feed as supplementary diets fed the fish once a day owing to algae growth in the pond and partly because of the escalating price of feed. Those who depend on algae could not afford to buy the feed. The farmers who use compounded feed included ingredients such as wheat bran, rice bran, fishmeal, and groundnut cake and soybean meal in the feed.

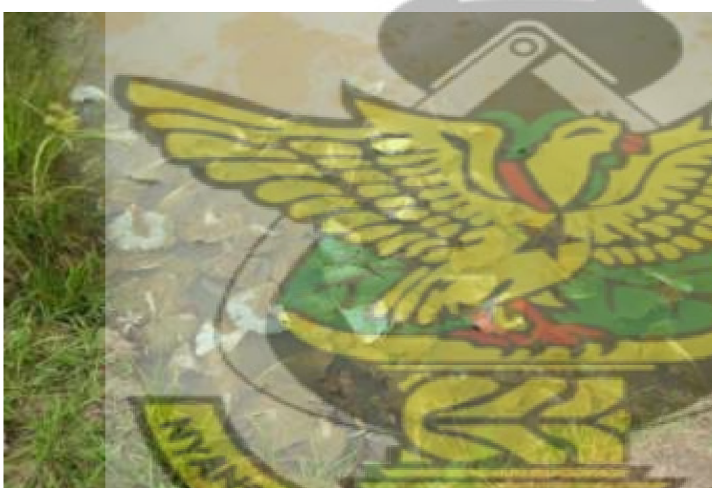

Plate 5: Cabbage leaves fed to *Heterotis niloticus*in a farm pond.

4.1.3.5. Sexual Differences

Farmers could not differentiate between the male and female by physical examination. However, some farmers guessed that the male is always slightly bigger than the female based on observations made when fish were being processed (degutted) after harvest.

4.1.3.6. Diseases

None of the farmers identified any disease associated with this species of fish on their farms. Apparently, this is an added advantage since the farmers would not have to worry about disease conditions on their farms.

4.1.3.7. Harvesting and marketing

Six or twelve month was set as cropping period by 20% of the farmers. Majority(60%) of the farmers had no idea about their cropping period. A larger percentage of farmers (80%) harvest their *H. niloticus* stock at body weights ranging from 1.5 to 3 kg. Only few (20%) had no idea of an estimated weight for harvesting. In all, 70% of the farmers had their fish surviving well where as 30% lost most of their fingerlings during grow-out. Fifty percent (50%) of the respondents sold to other farmers while 50% retained fingerlings in the for grow-out. Those who sold fingerlings transported the fish in ‘‘pig feet barrels’’ with four pieces of adult fish per tank or 200 fingerlings per tank.

4.1.3.8. Adoption of new species of fish and access to extension service

All the farmers surveyed were prepared to adopt new species of fish for culture other than tilapia and catfish, if given the opportunity. Some farmers (50%) had access to extension services from Ministry of Food and Agriculture and/ or Environmental Protection Agency. These extension service providers visit their farms at most twice a year whilst some farmers (50%) had no such opportunity.

4.1.4 Challenges faced by farmers

Major challenges facing all the *H. niloticus* farmers that need to be addressed for improved farming of this commercially important fish species include inadequate training in *H. niloticus* fingerling production practices and lack of access to extension services.

4.2 Nutritional Studies of *Heterotis niloticus*

Growth performance and feed utilization experiment was conducted on *H. niloticus* to determine the response to compounded feed with varying dietary crude protein levels: 26.17, 32.08, 34.61 and 42.81%. The performance in growth and feed utilization were determined in terms of weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR) and protein efficiency ratio (PER).

4.2.1 Proximate Composition of Ingredients and Diets

Proximate composition of ingredients and the diets used for the nutritional studies are presented in Tables 4.1 and 4.2. The values in Table 4.2 represent the corresponding percentage contribution of the experimental ingredients in relation to the crude protein, crude lipid, crude fibre, moisture content and ash content. The percentage compositions of the experimental diets analyzed after formulation are shown in Table 4.2. The gross energy of the four different diets is also shown in Table 4.2.

Table 4.1 Proximate Composition (% as fed) of ingredients used for diet formulation.

Ingredients	CP	CL	CF	MC	Ash
Fish Meal	69.66	11.28	0.65	8.83	13.11
Wheat Bran	18.93	8.15	7.87	12.47	4.68
Cassava Flour	0.84	0.41	2.05	11.97	2.65
Soybean Meal	45.48	7.53	4.76	11.15	6.77

CP=crude protein, CL=crude lipid, CF=crude fibre, MC=moisture content

Table 4.2 Proximate composition (% as fed) and gross energy (KJ g^{-1})) of experimental diets used in the nutritional studies.

	Experimental diet			
Parameter	**Diet I**	**Diet II**	**Diet III**	**Diet IV**
Crude protein (%)	26.17	32.08	34.61	42.81
Crude lipids (%)	9.82	9.07	8.84	9.39
Moisture (%)	2.97	4.79	4.50	3.34
Ash (%)	13.64	15.91	15.91	14.51
Crude fibre (%)	8.56	7.73	6.02	4.22
Nitrogen- free extracts (%)	38.84	30.42	30.12	25.73
Gross Energy (KJ g^{-1})	16.90	17.39	17.87	18.36

CP = crude protein, Gross energy values are calculated values

4.2.2 Acceptability of Experimental Diets by H. niloticus

Diet palatability was assessed subjectively by direct observation of fish behaviour and feeding responses. Fish from all treatments got adapted to the experimental diets within a week of feeding. The experimental tanks were free from algae. Initially, the response was very slow for all the treatments within the first 2 days as there were no feeding activities observed in the hapas. The fish practically picked the feed but drops the feed later and no faecal matter was observed in the hapas. On day 3 however, some fish were observed eating the feed bit by bit but faecal matter was observed in most of the hapas within day 6 and 7 for all treatments.

4.2.3 Growth Performance and Feed Utilization of *H. niloticus*

Growth performance of *Heterotis niloticus* under the four treatments in terms of weight gain (WG), specific growth rate (SGR), condition factor (K), feed intake (FI) and feed utilization efficiencies expresses as feed conversion ratio(FCR) are presented in Table 4.3.

Table 4.3 Growth and feed utilization of *Heterotis niloticus* fed at different inclusion levels of protein for 70 days.

Parameters	26.2 %CP (Diet I)	32.1 %CP (Diet II)	34.6 %CP (Diet III)	42.8 %CP (Diet IV)
IBW(g)	32.30±0.40	32.73±0.03	32.80±0.06	32.77±0.03
FBW(g)	65.56±4.57[a]	76.12±9.07[ab]	90.40±7.19[ab]	99.07±6.50[b]
WG(%)	102.80±12.42[a]	132.60±27.77[ab]	175.60±21.85[ab]	202.30±19.56[b]
FCR	1.85±0.17[a]	1.77±0.13[ab]	1.69±0.07[ab]	1.20±0.15[b]
SGR(%/day)	0.90±0.08[a]	1.06±0.15[ab]	1.30±0.11[ab]	1.41±0.08[b]
SUR(%)	93.33±6.67	91.67±8.33	73.33±13.33	71.67±17.40
PER	2.10±0.16	1.82±0.30	2.18±0.21	2.00±0.16
FI(g)	60.49±3.45	74.33±10.14	76.53±8.69	77.45±3.06
K	2.46±0.16	2.48±0.29	2.19±0.14	2.06±0.24

IBW (g)=Initial body weight, FBW (g)=Final body weight, WG (%)=Weight gain, FCR =Feed conversion ratio, SGR ($\%day^{-1}$)= Specific growth rate, SUR (%)= Survival, PER=Protein efficiency ratio, FI (g)=Feed intake, K= Condition factor, CP= crude protein. Mean values (±SE,n=3) in the same row with different superscript are significantly different (P< 0.05)

Protein efficiency ratio (PER) and the percentage survivals in each treatment are also shown (Table 4.3). Whole-body composition of *Heterotis niloticus* is shown in Table 4.4.Fish fed the various experimental diets grew at varied rates during the study. Fishes fed Diet IV attained the highest mean body weight of 99.07g with a weight gain of 202.30%. Fish fed Diet I obtained the lowest mean final body weight of 65.56g with a weight gain of 102.80%. There were no significant differences (P> 0.05) in the meaninitial body weight of the fish. However, the mean final body weight and the percentage weight gain were significantly (p>0.05) affected by dietary protein level. Fingerlings of *Heterotis niloticus* fed with 42.81% protein diet differed significantly (p<0.05) from those of 26.2, 32.1 and 34.6% protein diets in terms of mean final body weight and percentage weight gain. However 32.1 and 34.6% protein diets showed no significant differences in the mean final body weight and percentage weight gain (Table 4.3).The growth performance of the fingerlings for the different treatments is graphically shown in Fig. 4.1. From the graph, there were sharp growthsfrom the initial values in all the four dietary treatments from the first to the third week of the study. However, between the third and eighthweek, growth in the four different treatments increased at a decreasing rate, forming a growth plateau. Subsequently, sharp growths were observed in the four dietary treatments from the eighth to tenth week when the experiment was terminated.

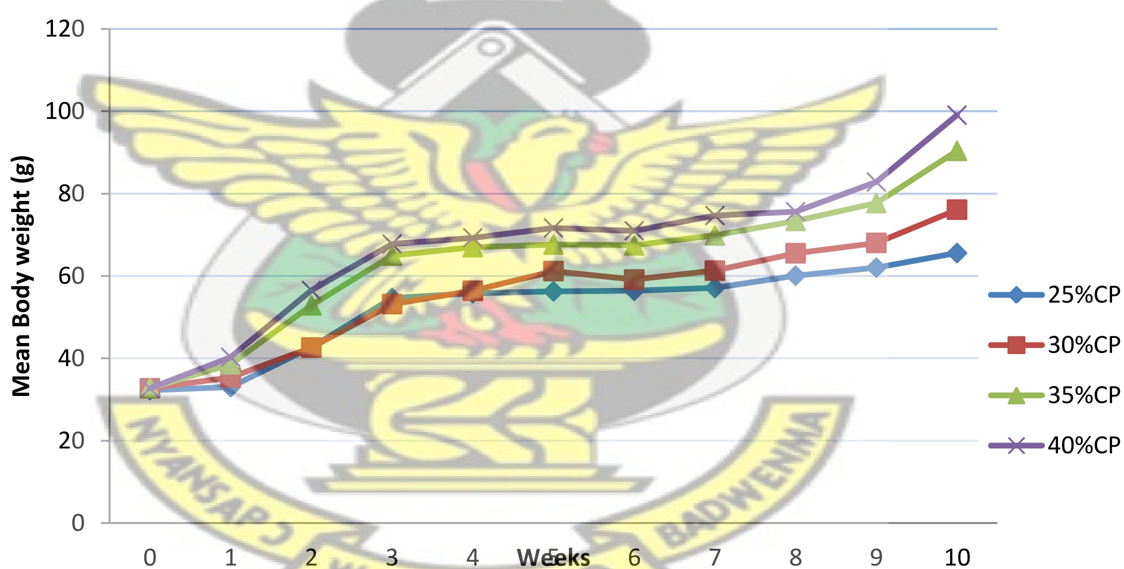

Figure 4.1 Growth performance of *H. niloticus* fed at different inclusion levels of protein for 70 days.

The specific growth rate was also significantly affected by dietary protein level ($p<0.05$). Fish fed with 42.8% protein diet showed the highest specific growth rate (1.41%/day) and value differed significantly ($p>0.05$) from that of diet with 26.2 % crude protein (Table 4.3). However, 32.1 and 34.6 % protein diets showed no significance ($p>0.05$) differences in the specific growth rate. Fishes fed 26.2% protein diets showed the lowest specific growth rate (0.90%/day) (Table 4.3).

The survival was highest (93.33%) for fish fed the 26.2 % crude protein diet (Diet I) and fish fed the 42.8%crude protein diet exhibited the lowest survival (71.67%) (Table 4.3). However, there were no significant differences ($p>0.05$) in survival among treatment diets. Even though survival rate was not significantly different for the four treatments, survival rate decreased with increasing levels of dietary protein (Table 4.3).

Feed intake (FI), was highest (77.45g) for Diet IV and lowest (60.49g) for Diet I. There was however no significant differences ($p >0.05$) among the treatment mean of the four different diets (Table 4.3).

The FCR, showed similar trend as the WG and SGR. A decreased trend in FCR was observed when crude protein increased. Fingerlings fed 26.2 % crude protein diets obtained the highest mean FCR (1.85) whereas those fed 42.8% protein diet exhibited the lowest mean value of FCR (1.20) (Table 4.3).

The PER showed no significant difference (p>0.05) among the four treatment diets(Table 4.3). However, PER value (2.18) was highest for 34.6 % protein diet (Diet III) and lowest (1.82) for 32.1% protein diet (Diet II).

Fish fed Diet II obtained the highest average condition factor of 2.48±0.29g^{cm-3}with the lowest being 2.06±0.24g^{cm-3} with fish fed Diet IV (Table 4.3). There was no significant difference among treatment diets evaluated.

4.2.4 Whole Body Composition

There were no significant differences (P > 0.05) in the whole body composition of fish (Table 4.4) fed diet of varied protein composition. However, Fish fed Diet IV recorded the highest percentage body crude protein (18.54%) and crude lipid (1.71%) while fishes Diet I recorded the lowest percent protein (17.77%) and lipid (1.65%).Fishes fed Diet III recorded the highest percent body moisture (76.35%) whereas those fed with Diet IV recorded the lowest percent body moisture content (75.03%). Percentage body ash (1.56±0.10%) was highest for fish fed diet IV and lowest for fish fed Diet III (1.44%). The percentage body crude fibre (0.14%) was marginally lower for fish fed Diet I compared to those fed Diet II, III and IV which recorded the same value (0.15%) of crude fibre.

Table 4.4 Body compositions (% wet weight) of *Heterotis niloticus* fed diets with different inclusion levels of crude protein (CP) for 70 days feeding trials.

	Initial value	Experimental Diets			
Parameter		**26.2 %CP**	**32.1%CP**	**34.6%CP**	**42.8%CP**
Crude Protein	18.66 ± 0.21	17.77 ±0.42	18.40 ±0.56	18.43 ±0.38	18.54 ±0.71
Crude Lipid	1.66 ± 0.03	1.65 ±0.12	1.57 ±0.05	1.69 ±0.03	1.71 ±0.03
Moisture content	74.25 ± 0.26	76.02 ±0.71	75.22 ±0.72	76.35 ±0.50	75.03 ±0.95
Ash	1.59 ±0.04	1.51 ±0.14	1.51 ±0.04	1.44 ±0.04	1.56 ±0.10
Crude Fibre	0.13 ±0.01	0.14 ±0.01	0.15 ±0.11	0.15 ±0.01	0.15 ±0.01

CHAPTER FIVE: DISCUSSION

5.1 Assessment of Indigenous Knowledge of *Heterotis Niloticus*

Results of the survey to assess H. *niloticus* aquaculture in Ghana in this present study indicate that culture of this commercially important fish species is at the infant stage. Only few of the farmers were engaged in the culture of this species. However, success of a fish species in aquaculture depends on the production and the availability of fingerlings for supply to fish culture centres (FAO, 1991; Egna and Boyd, 1997; Rønnestad et *al*., 2001; Adite *et al*., 2005, 2006; Monentcham, 2009). Farmers surveyed in this study were trained mostly on culture practices of main traditional fish species (Tilapia and catfishes) that are farmed in Ghana and were not exposed to any training on how to handle *H. niloticus* in aquaculture. This may be due to lack of extensive research on the bony-tongue as compared to the common traditional species that are tamed in Ghana. Majority (75%) of the farmers surveyed observed both adult and juvenile *H. niloticus* in their ponds. However, they could not differentiate between the sexes because female and male fish had similar external morphometric characteristics. The farmers, however, surmised that males were larger than females when examined during processing (degutted) at harvest. Moreau (1982) reported that gender in *H. niloticus* can be determined only by macroscopical examination of gonads because both the male and female have similar external features. Few (25%) farmers had no knowledge on the ecology of the fish. The fish were noted to spend most of their time in vegetated areas of the pond where they were normally spotted by famers when feeding on insects and tinny seeds that floated on the surface of the pond water. These feeding observations by farmers agree with Lowe-McConnell (1975), Lauzanne (1976) and Hickley and Bayley

(1987) who also reported similar feeding behavior of *Heterotis niloticus*. Compounded feed was used by some farmers as supplementary diets while others did not use compounded feed at all because of the high prices of imported fish feed which most farmers could not afford. Thus, supplementary feeding or no feeding was practiced in raising *H. niloticus*in their ponds. However, all the farmers surveyed depended on natural foods produced when ponds were fertilized with external inputs mainly manure, for maintenance of the species in their ponds. Few farmers compounded their own feed using locally available materials derived from fishmeal, soybean meal, wheat bran and rice bran to feed their fish in the ponds. Brown *et al.* (2002) indicated that reducing feeding rates either by delaying the introduction of feeds or by feeding less than the amount required for satiation had no effect on growth or yield of fish reared in fertilized ponds, indicating that this approach may be favourable to farmers wishing to reduce costs without compromising sales. Moreover *H. niloticus* are omnivores and are able to find a lot of food organisms in a fertilized pond which could make their production cheaper.

Rainfall and the presence of vegetation were some of the conditions that may induce spawning as suggested by farmers. The availability of fresh water during the rainy season probably would have increased the spawning frequency which would increase fingerling output. Adite et al. (2005) who studied reproductive behaviour of the *H. niloticus* in the wild, found that more than 85% of the nests of the species were active in the rainy season (April- October). Similarly, Padi (2006) who studied the species under artificial conditions in earthen ponds observed that rainfall intensity influenced reproduction in the species. Fish farmers in Ghana rely mainly on *H. niloticus* fingerlings caught from the wild. This might be because the wild serves as a reliable and more constant source of stock for most farmers (Padi, 2006). Unreliability of fingerling supply from wild source has created situation where stocking rates were not rationalized on the farm. This is because most of them did not get enough stock from the wild or other farms. Hence any quantity of fish they had could be stocked into any available pond. Tamas and Horvath (1979) noted that fish farming begins with the stocking of fry, either from the wild or produced on the farm and whatever their origin, they are indispensable and the means of obtaining them influences directly farm production. Thus, the regular supply of fingerlings among farmers surveyed negated maximization of farm fish yield in their operations. The generally high survival of *H. niloticus* in majority of farm ponds may be due the relatively large size at which fish was stocked in the ponds. Dinis et al. (2000) reported that post-fingerling stage of fish have a well-developed alimentary canal which enabled them to process complex food organisms. The age of fish, predation, environmental stress, parasites and diseases and fishing activity are some of the factors which cause fish mortality (King, 1991; (Otobo, 1993, Chapman and Van Well, 1978; Landau, 1979).Furthermore, the inability of fingerlings to handle compounded feed because their digestive tracts were not well developed may also contribute to reduced survival (Watanabe and Kiron 1994; Breine and al., 1995; Rønnestad et al., 2001). Moreau (1982), reported that larvae of *Heterotis niloticus* like many fish species, exhibit a very high mortality rate ranging between 80% to 100%. The absence of any observed disease by farmers raising *H. niloticus* is an added advantage to the commercialization of the species.

Monentcham *et. al.* (2009) reported a body mass of 3 to 4kg in 12 months. The harvest weight 1.5-3Kg reported by farmers in this study overlap the weight range (3-4Kg) reported by Monentcham *et.al* (2009).

One hundred percent (100%) of the farmers were prepared to adopt new species of fish including *H. niloticus* for culture other than tilapia and catfish, if given the opportunity. However, access to appropriate feeds at reasonable prices, adequate extension services and adequate training in hatchery operations were some of the factors that would boost the adoption of *H. niloticus* as reported by farmers in this present survey. These observations by farmers agree with Adite *et al.*,(2005) and Moreau (1982), who noted that more information is needed on natural feeding habitats and nutritional requirements of the species in order to inform both fisheries management and development of aquaculture technology as far as the ecological and economic importance of this species is concerned.

5.2 Growth Performance, Feed Utilization and Body Composition

In the present study, different dietary levels of crude protein (CP) inclusion influenced final body weight (FBW) of *Heterotis niloticus*. Fingerlings of *H. niloticus* fed diets I (26.2% crude protein) and IV (42.8% crude protein) showed major distinction in the final body weights whereas fingerlings fed diets II (32.1% crude protein) and III (34.6% crude protein) exhibited no distinction in the final body weight. The same is true for percentage weight gain (WG %) and specific growth rate (SGR). *Heterotis niloticus* fingerlings fed diets I and IV showed major differences whereas those fed diets II and III showed no major difference in the mean weight gain and specific growth rate of the fish (P > 0.05). Observed increased mean FBW and WG of *H. niloticus* when this species was fed increased with increasing levels of dietary protein. These results are in agreement with (Al-Hafedh *et al.*, 1999) who found that the better growth of Nile tilapia was obtained at high dietary protein levels 40-45 % rather than 25-35 % protein in the absence of live algae. It however disagrees with Monentcham *et al.*, (2009), who recorded maximum WG for *Heterotis niloticus* fingerlings when the dietary protein level was 34%. The specific growth rate recorded in this study (0.90-1.41% day^{-1}) is slightly higher than those reported by Al-Hafedh (1999) for other omnivores such as Nile tilapia (0.45-0.75%day^{-1}). However, it slightly corresponded with the specific growth rates (1.36 and 2.77% day^{-1}) actually reported for *Heterotis niloticus* juveniles (30-50g) under favourable condition of feeding and 0.87% day^{-1} under unfavourable condition of feeding (Bard, 1960).The specific growth rates recorded in this study are however; lower than those (2.5 and 3.1% day^{-1})reported by Monentcham, (2009) for juvenile *Heterotis niloticus.*

The condition factor (K) was not affected by the varying levels of protein inclusion in the diets. The K values ranged from 2.06- 2.46(from Table 4.4).Estimated values in this study are in close agreement with those of Osman, (1991) who reported that K values in general, for fish ranged between 2.20 - 2.33. Similary, estimated K values agree with (Ahmad *et al.*, 2004)

Fingerlings of *H.niloticus*fed diet IV (42.8% CP) obtained the best FCR whereas fingerlings fed diet I (26.2%CP) recorded the poorest FCR value, which means that

42.8% CP diet was more efficiently utilized. The decrease in Feed Conversion Ratio (FCR) in this study, suggests an increase in feed conversion efficiency. According to Lovell, (1989) protein is the major dietary nutrient affecting performance of fish. Protein also provides essential and nonessential amino acids which are necessary for muscle formation and enzymatic function and in part provides energy for maintenance (Yang *et al.,* 2002). Gunasekera *et al*. (2000) reported that the best growth and Feed Conversion Ratio (FCR) were observed in a diet of high dietary protein to a certain point and decreased with further increase in dietary protein content. In the present study no decreased growth was observed with increased protein level. This would be because of the decrease in protein use efficiency with increasing age as dietary protein reach and exceeds their requirements in the fish.

The increased trend in feed intake (FI) with increased protein level may probably be due to increased palatability of feed when CP has increased. Monentcham (2009) made similar observations on feed intake when protein level was increased for juvenile *H. niloticus*. The same author suggested that the level of protein in artificial diets for *H. niloticus* may affect survival and growth performance of both larvae and juvenile. Moreau (1982) suggested that the combined effects of these causes could act to increase the mortality of *Heterotis niloticus* larvae. Fish used in this experiment were juvenile (32.3g). Thus, the relatively high survival observed in the present may be due to the highly developed digestive tract which allowed them to process the artificial diet fed them. According to Rønnestad (2001), the digestive system of fish larvae is the foremost cause for low survival and low growth rate and plays a central role in nutrient acquisition after the resorption of the yolk. Monentcham (2009) suggested that late weaning at 24-26 days after hatching (DAH) is relatively efficient in improving *Heterotis niloticus* larvae survival and growth factors. Dinis *et al*. (2000) further suggested that only 31 DAH larvae had a morphologically complete digestive tract enabling them to absorb complex nutrients.

In this present study, whole-body protein, lipid, moisture and ash levels were not significantly affected by dietary protein levels. Similar results were observed in the carcass composition of Nile tilapia (El-Saidy and Gaber, 2005). Yang *et al*. (2002) also reported that body ash content was not influenced by dietary protein level when fishmeal was used as the main protein source for investigating the dietary protein requirement of fish.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

There is ever increasing pressure on the wild fisheries resources as Ghana's population increases. This has led to the use of indiscriminate fishing gears in our water bodies to trap all kinds of fish, both mature and immature fish leading to the depletion of fish species in our water bodies (both fresh and marine) thus, causing imbalance in the eco-system. In Ghana aquaculture has been adopted as an assured means of meeting the national demand for fish. The practice of aquaculture will therefore ease the pressure on the nation's wild stock of fish. However, aquaculture in Ghana is limited to the production of few species namely the tilapia and catfishes. What becomes of the nation in future should these species be wiped away by strange epidemic? There will certainly be depression in Ghana's aquaculture sub- sector since the aquaculture sub-sector has no clear policy frame for the development of other native species with aquaculture potential, such as the African bony tongue and the Claroteid catfish. Development of these alternative species will buffer the few cultured species and bring about variety in the number of species cultured in Ghana. This will also ease pressure on wild species therefore ensuring biodiversity conservation and balance in the eco-system.

The principal aim of this research was to evaluate the potential of *Heterotis niloticus* as fish for culturing in Ghana by gathering information from literature and fish farmers and to conduct experiments that could enhance knowledge on the nutritional requirements of African Bony-tongue.

The research therefore had these specific objectives;

- To assess farmers' indigenous knowledge of *H. niloticus*
- To evaluate the growth performance, feed utilization and whole-body composition of *H. niloticus* fed onvarying dietary protein levels.

Based on the above objectives the following conclusions were made:

- Indigenous information given by farmers on *H. niloticus* in this study indicates commercial potential for *H niloticus* with the rising interest of farmers in the culture of this species. However, access to extensive research information on the production of this species is crucial for any meaningful commercial culture.
- Nutritional studies also indicate that *Heterotis niloticus* will feed on formulated diets in captivity. The results indicates that FBW,WG and SGR increased with increasing dietary protein levels with maximum values in the 42.8% protein diet, although this was not significantly different from the 32.1% and34.6% protein diets. Whole body composition was not significantly different between the diets. In conclusion, the use of a practical diet containing at least 32.1% protein would be appropriate for the growth and nutrient utilization of juvenile *H. niloticus* under the conditions of this study. Although 42.8% dietary protein gave the best growth, the optimum protein requirement was not established because no growth plateau was found. Generally, fish reach a plateau and subsequently show decreased weight gain or specific growth rate when dietary protein levels reach and exceed their requirements.

6.2 Recommendations

The following recommendations should be considered for any future study:

- Even though *Heterotis niloticus* may be accepted in the communities where they are available, further research work should be conducted on the acceptability of this species to consumers, market availability and demand and the form (whether fresh, smoked or salted) in which the fish is acceptable to consumers.
- Research works on indigenous species development should be encouraged and the research findings should be made available to farmers since farmers on their own initiatives are culturing some of these species with little or no research information available to them to enhance commercial culture.
- The fish should be at least 30g before stocking into concrete tanks under the conditions of this study since serious mortality was encountered when fish below this size were stocked.
- The number of dose-response points should be increased in any future research similar to this since the 4 response points used in this research could not reach a growth plateau in order to establish exactly the optimum protein requirements for *H. niloticus*.

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APPENDICES

Appendix 1

ASSESSMENT OF INDIGENOUS KNOWLEDGE ON ECOLOGY, LIFE-HISTORY AND NATIVE DISTRIBUTION OF *HETEROTIS NILOTICUS*

QUESTIONNAIRE FOR FISH FARMERS

This questionnaire is intended for research purpose only. It is designed to find out how to determine the current status, opportunities and constraints for aquaculture development in the Ghana. You are therefore assured that any information given would be kept confidential.

INSTRUCTIONS: you are humbly requested to fill in the Blank spaces and tickin the box where appropriate.

1. BIODATA

Sex: Male ☐ Female ☐

Age: ………………..

Level of Education: Basic level ☐ Secondary level ☐

Tertiary ☐ None ☐ other (specify):…

Main occupation................................... Minor occupation (if any)…………..

2. FISH FARM STATUS

2.1 Name of farm..

2.2 Location of farm...Region...........................

2.3 Did you have any special training in fish farming? Yes ☐ No ☐

2.3.1 If yes specify...

2.4 How many years have you been in this business?

a. 0-5 years ☐ b. 5-10 years ☐ C. 10 years and above ☐

2.5 What is the size of your farm (in hectares)..

2.6 How many ponds do you have? ....

2.7 What culture system are you practicing?

a. Monoculture ☐ b. Poly culture ☐

c. Integrated fish farming ☐

2.8 What are the regular species of fish farmed (*Please, list them*)

....

....

2.9 Where do you get your stock of fish from?

a. From the wild ☐ b. From other farms ☐

c. Research Institutions ☐

2.10 How far is the source of fingerling from your farm? (*Please, state*)

………………………………………………………………………………

2.11 How regularly do you feed your fish? (*Please, state*)

………………………………………………………………………………

2.12 Do you make your own feed? Yes ☐ No ☐

2.13 If yes what ingredients do you use?

……………………………………………………………………………..

2.14 Where do you get your ingredients from?

………………………………………………………………………………

1.0 INDIGENOUS KNOWLEDGE ON *H. NILOTICUS*

1.1 Do you culture this species of fish? ***African bony-tongue*** Yes ☐ No ☐

1.2 Where do you get your fingerlings from? a. From the wild ☐

b. From other farms ☐ c. From government institutions

d. Others source ☐

1.3 How far is the source of fingerling from your farm?

……………………………………………………………………………………

1.4 At what size do you stock your fish?

…………………………………………………

1.5 What is your stocking rate?

…………………………………………………………..

1.6 How long does it take you to produce economic size? (in *months*)……….

1.7 At what size do you harvest your fish? (*in kg*)……………………………

1.8 What culture system do you use

a. Pond ☐ b. Concrete tanks ☐ c. Pen culture ☐

1.9 What is your source of water?

a. Rain ☐ b. Groundwater ☐ c. River ☐

1.10 Do you change your water regularly? Yes ☐ No ☐

1.11 How do you ensure quality water on your farm? (*Describe*)

……………………………………………………………………………………

1.12 What type of soil exists at your production site?

Clayey ☐ loamy ☐ sandy ☐ Other (*specify*)……

1.13 Do you have vegetation around your pond? Yes ☐ No ☐

1.14 Do you have vegetation in your pond? Yes ☐ No ☐

1.15 What is the natural habitat of your fish?

………………………………………………………………………………

1.16 How would you describe the feeding behaviour of the fish?

a. Surface feeding ☐ b. Bottom feeding ☐

1.17 Where do you find the young ones?

………………………………………………………………………………

1.18 What time of the year do you get/find the young ones? ………………….

1.19 Do you know any condition under which they spawn? (*Please, state*)

1.20 Do the young ones survive well in your system? Yes ☐ No ☐

1.20.1 If yes, how did you ensure their survival?

……………………..……………………………………………….

1.20.2 If no, what in your view causes the mortality?

……………………………………………………………………

1.21 Do some farmers buy the young ones from you? Yes ☐ No ☐

1.21.1 If yes, how do you package and transport the young ones?

……………..……………………………………………………………………

1.22 How many young ones do you have per package?..

1.23 How do you tell the difference between the male and female?

………………………………………………………………………………

1.24 Do you know of any natural food they feed on? Yes ☐ No ☐

1.24.1 If yes, state the food(s)..

1.25 Have you ever tried giving them compounded feed before?

Yes ☐ No ☐

1.25.1 If yes, state the major ingredients used for your formulation

……………………………………………………………………………..…….

1.25.2 Did this formulation give you the expected result?

Yes ☐ No ☐

1.26 How easily can you access these ingredients?

…………………………………

1.27 Have you identified any common disease(s) with this fish?

Yes ☐ No ☐

1.27.1 If yes, list them……………………………………………………..

1.28 Do you have any other economic species in mind for research to be done on? Yes ☐ No ☐

1.28.1 If yes, list them..

1.29 Should research establish new economic species would you adopt them?

Yes ☐ No ☐

1.30 Do you have access to the extension services? Yes ☐ No ☐

1.30.1 If yes, how often do you access extension services?.....................

1.31 Do you have any other problems? Yes ☐ No ☐

If Yes, List them