REPRODUCTION, LARVAL REARING AND THE INFLUENCE OF DIETARY PROTEIN LEVELS ON THE GROWTH OF THE CATFISH CHRYSICHTHYS NIGRODIGITATUS (LACEPEDE)

by:

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A thesis in the Department of Zoology submitted to the College of Science and Technology in partial fulfilment of the requirements for the degree of Doctor of Philosophy of the University of Ibadan, Nigeria.

1992

Abstract

Reproduction and early development were studied in the catfish Chrysichthys nigrodigitatus (Lacepede). From the monthly analysis of gonado-somatic indices it was shown that the species had an annual reproductive cycle that falls into four distinct phases. The gonad preparatory phase was observed between September and December, the prespawning or maturing phase was between January and February, the spawning phase was in March and April and possibly May while the resting phase occurred during June to August. In the males, two distinct reproductive phases were indicated. These were the gonad preparatory phase or growth phase which occurred between July and February, and the spawning phase which occurred during March to May. C. nigrodigitatus was observed to store up lipids in its muscle and liver during the initial period of gonadal growth. The lipids were later utilized for gonadal maturation, spawning activities and parental care.

Observed environmental features coinciding with spawning in sexually mature individuals in Asejire lake included low water level, presence of suitable spawning substrate, direct contact with mature partner

in the basence of light and a gentle flow of water across the spawning substrate. In the presence of these features, spawning occurred within 48 hours when gravid male and female were paired in Asejire lake. The fertilized eggs from the Asejire stock hatched in the laboratory between 48 and 50 hours. The development and growth of the early larvae are described.

Results of two weeks of exogenous feeding trials showed that the larvae of C nigrodigitatus fed on live plankton had specific growth rate of 13.24 and 26% survival while those fed on 40% crude protein level had specific growth rate of 1.46 and 2% survival. Larvae fed on 35% and 30% dietary crude protein levels survived for only 5 days.

Effects of different levels of crude protein diets fed to fingerlings, juvenile fish and adults of both sexes were evaluated. It was found that the fingerlings and juvenile fish had best growth in the diet containing 35% crude protein. The male and female adults had best growth on 25% and 35% crude protein respectively.

Results of carcass analysis showed that the percentage of body fat increased significantly ($P < 0.05$) with increasing dietary protein levels while there was no significant ($P > 0.05$) increase in the percentage of body protein. This suggests that the weight gain in the fish resulted from fat deposition. The general increase in the percentage of body fat of the adult fish compared with that of the young fish further confirm that fat deposition is an essential energy reserve in preparation for breeding season.

Dedication

This work is dedicated:

- To God the Father, the Son and the Holy ghost.
- To my loving father, late Mr. E.A. Aboaba.
- To my caring and loving mother Mrs. R.M. Aboaba.
- To my darling husband, Mr. A.S. Adewolu.
- To my beautiful daughters Opeoluwa and Oluwaseun.

Acknowledgement

I praise the almighty God for seeing me through this work. I express my profound gratitude to my supervisor Professor S.O. Fagade for his constructive criticism and valuable advice. I also like to thank Dr. A.A. Adebisi, Dr. (Mrs.) Jeje and Dr. & Dr. (Mrs.) Alex Ugwumba and other members of staff of the Department of Zoology, University of Ibadan for their precious advice and encouragement.

My special appreciation is extended to Dr. A.E. Falaye, Dr. A.M. Balogun and Miss Yemi Aboaba for their objective criticism on the nutritional aspect of this work. Great acknowledgement is extended to Professor Afolabi Toye, Dr. Titi Hassan, Dr. Oba Fagade and Dr. 'Remi Idowu for monitoring the progress of this work with keen interest.

I also wish to thank the entire members of Aboaba, Adewolu, Akinbode, George and Adesiyun families for their moral support.

My gratitude also goes to my friends and colleagues Ms. Dupe Adelusola, Ms. Parcy, Mrs Betty Bamigboye, Mr. John, Mr. Araoye, Mr. Opadiya, Dr. Martin Anetekhai;

Dr. (Mrs.) Ibidapo; Dr. (Mrs.) Elemo, Dr. (Mrs.) 'Sena Bakare, Ms. Titi Adegoroye, Dr. (Mrs.) Nwaboku, Miss Oloruntuyin, Mrs. R.M. Lawal, Ms. Deola Ladapo, Mrs. 'Bola Adegun and others who have contributed to the success of this work.

I must not forget to thank my people in Offa, Mrs. Adebo (Mummy nurse), Mrs. Ajiboye (mistress), Mrs. Olarewaju (Iyabode), Afusa, Dupe, Ester, Charity and others for their love.

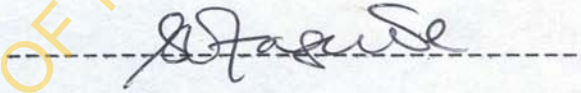
I am also grateful to the Head of Department and entire members of staff of the Department of Fisheries and Zoology of Lagos State University for their encouragement and support. I acknowledge Lagos State University for sponsoring this programme.

My deep sense of appreciation goes to my mother, my husband, my sisters and brothers and my daughters for their love, moral and financial support.

Finally, I thank the Almighty God once again, for His mercies, my saviour Jesus Christ for His love and the Holy Spirit for His strength.

Certification by Supervisor

I certify that this work was carried out by Miss Morenike A. Aboaba in the Department of Zoology and hereby recommend that this thesis, prepared under my supervision, be accepted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.



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Chapter 1

1.1 General Introduction

One of the serious problems confronting the developing countries today is how to match food production level particularly, the proteineous foods in relation to their demand by the increasing human population. The magnitude of this problem is shown in the prevalence of kwashiorkor and other diseases associated with protein deficiencies.

In Nigeria, the average protein intake is very low (Oyenuga 1972, 1980; Fetuga 1975). It is estimated as 62g per day, a large proportion of which is from plant sources and a very small portion is from animal sources. This low protein intake in the country is below the FAO (1975) recommendation of 70g per day, half of which must come from plant sources and the remaining half from animal sources. It is therefore, desirable that the production of animal protein through the development of livestock and fisheries be encouraged. The problems of livestock

production have been highlighted by Oyenuga (1963, 1969, 1973, 1980) and FAO (1980). There is a long waiting period for most of these animals to reach slaughtering weights since they require a lot of energy to develop a complex skeletal system for general support against gravity. In contrast, fish lives in an environment that supports its weight and requires no energy to develop complex skeletal system. It, therefore, has more energy to convert food consumed into body protein. In this respect, Bardach et al; (1972) reported that the feed conversion rates for fish are one to one-half times as for chicken and swine and about twice as great as for cattle or sheep. Increasingly therefore, a kilogram of fish can be produced more cheaply than a kilogram of meat. Besides, it is the most easily digestible of all the dietary proteins (WHO, 1965, FAO 1986). Human beings can utilize at least 83% of its raw weight (WHO, 1965). It is rich in vitamins, minerals, and provides a good balance of amino acids (Nose, 1971, Talabi, 1982 and Viola and Arieli 1982). It is also rich in polyunsaturated fatty acids which keeps blood cholestrol

levels low and reduce the risk of coronary heart disease (FAO 1986). People whose source of protein comes mainly from the fish especially people living along the coast are healthy, tall and vigorous (Bell, 1975). In this regard, fish can be a useful tool to supply the urgent protein needs of Nigerians.

1.2 Level of fish production in Nigeria

The fish production trend by various sectoral fisheries from 1980 to 1989 is presented in Table 1. The artisanal sector contributed more than 50% to the total annual fish production. The contribution from industrial sector is about 5%, while aquaculture contributed less than 3% (FDF 1990). The contribution from fish import is about 45%. It is obvious that fish production through aquaculture is low, and it is, therefore, necessary to emphasize and encourage the development of aquaculture.

1.3 Aquacultural development in Nigeria

The history of fish farming in Nigeria is young when compared with other agricultural practices. It started in 1944 after the second world war with the

Table 1 - Nigeria fish supply by sectors (1980 - 1989) (unit metric tons)

Sectors	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
(1) Artisanal										
Coastal and Brackish water	274,158	323,916	377,683	376,984	246,784	140,873	160,169	145,755	185,181	171,332
Inland: Rivers and lakes	188,409	157,867	119,527	146,267	112,219	60,510	106,967	103,232	112,443	132,607
Fish farm (Aquaculture)	-	-	-	20,476	22,012	15,000	14,881	15,221	15,764	25,607
(2) Industrial (Commercial trawlers)										
i) Fish	11,667	7,070	17,348	13,951	22,992	23,766	22,419	21,383	32,740	28,411
ii) Shrimps	1,964	2,541	1,513	5,294	2,658	2,376	2,623	3,517	2,868	5,234
iii) EEZ	-	-	-	-	-	-	-	-	941	-
(3) Distant: (imports)	121,144	168,769	404,413	131,308	147,261	61,704	65,242	209,042	113,603	313,987
Total:	597,342	660,163	920,484	694,280	553,926	304,229	372,301	498,150	463,540	676,693

Source: FDF (1990)

primary aim of increasing protein intake of the villagers. Its development spread to towns, and, in 1952, the Panyam fish farm of the then Northern Nigeria was constructed (NFDC 1979). Later many fish ponds sprang up as a result of the "grow your own fish" campaign of 1964. As at 1975, more than 2,000 fish ponds covering a total area of more than 1,000 hectares were scattered all over the country (Dada, 1975). Recently, a new government programme for the development of aquaculture in Nigeria was proposed. The goal is to make Nigeria self-sufficient for fish by the year 2,000 (FDF 1988). Today, desirable species like Tilapia spp., Heterotis niloticus, Cyprinus carpio, Gymnarchus niloticus, Lates niloticus, Clarias gariepinus and Chrysichthys nigrodigitatus are cultured in ponds.

1.4 Chrysichthys nigrodigitatus as a culturable species

Chrysichthys nigrodigitatus is indigenous to Africa (Hem 1985). It occurs naturally in fresh and brackish waters (Ezenwa 1978). The fish is

hardy enough to tolerate wide changes in salinity and dissolved oxygen (Ezenwa 1978). Fagade and Olaniyan (1973), Ikusemiju and Olaniyan (1977) described C. nigrodigitatus as omnivorous feeder, suggesting that the fish could be raised successfully on selected feed ingredients of both plant and animal origin. Coche (1982) and Ezenwa (1982) in seperate papers on the feeding of C. nigrodigitatus using groundnut cake reported that the fish show high food conversion ability, good growth rate, high coefficient of condition and survival. Based on the above characteristics viz:- good growth rate, acceptance of artificial diets, high food conversion efficiency, and hardiness in terms of high tolerance of low oxygen and salinity. Afinnowi and Morioghae (1986) reported that C. nigrodigitatus is cultured in both freshwater and brackish water.

Although C. nigrodigitatus does not spawn naturally in ponds (Ezenwa 1976; and Hem 1982), Hem (1985) reported that the fish was made to breed in an enclosure made of plastic tubes when placed in Lasjo lagoon in Ivory Coast. In Nigeria, information on

the artificial propagation of the fish is scanty, fingerlings are still collected from natural sources to stock the ponds where they are raised to market size. Ezenwa (1982) and Ibrahim (1985) reported that the fish is highly cherished by many people in Nigeria. It is of great demand and enjoys excellent market. There is therefore the need to culture this fish intensively.

However, the intensive culture of C. nigrodigitatus requires an understanding of its reproduction, spawning, larval rearing and response of the fish to artificial diets. Each of these areas is intimately related to other and it is only through the proper understanding of the reproduction that the fish can be induced to spawn. Also, the efficient production and growth of fish depend on the effective utilization of artificial diets.

In view of the above, the present work was designed:

(1) To study some aspects of reproduction of C. nigrodigitatus in Asejire lake with a practical view of inducing C. nigrodigitatus to spawn

(2) To evaluate the nutritional state of the fish during the different stages of gonadal development with a view to determining the level of nutrient reserves, its mobilization and utilization at different stages of gonadal cycle.

(3) To elucidate the sequence of development and growth of the larvae to fry under laboratory conditions.

(4) To determine the influence of dietary protein levels on growth and nutrient utilization of C. nigrodigitatus with a view of determining the optimum dietary protein requirement at different stages of the life cycle.

Chapter 2

2.0 Literature review

2.1 Taxonomic status of C. nigrodigitatus

The catfish - Chrysichthys nigrodigitatus is a siluroid fish of family Bagridae and subfamily Chrysichthynae. Three other species were identified in Nigerian waters as C. walkeri, C. furcatus and C. auratus longifillis (Holden and Reed 1972).

Generally, C. nigrodigitatus has 16 dorsal rays, 19 pectorals, and 14 - 15 anal rays of which 9 - 10 are branched. There are 15 - 18 gill rakers on the lower part of anterior arch. The caudal fin is deeply forked and has the upper lobe prolonged into a filament. The snout is relatively long and obtusely pointed. There are three pairs of barbels; one pair on the upper jaw, which are longer and the rest two shorter pairs are on the lower jaw. The colour of the fish is bluish-grey dorsally and whitish ventrally. Fins are rosy grey, adipose blackish, lips and barbels are pink. The fish may attain a body length of 50 cm and weight of 10kg (Holden and Reed 1972).

2.2 Habitat/Environmental conditions

The typical habitat of C. nigrodigitatus is in freshwater and brackish water. It is a warm water species and it is usually found on soft ground at the mouth of great rivers, lakes and coastal waters where there are roots and tangles of plants. The fish can live in waters with low concentration of dissolved oxygen. It can perform well in water temperature of 20 - 30°C and can withstand pH of 6.0 - 9.0 and salinity level of 0 - 26% (Ezenwa, 1978).

2.3 Food and feeding habits

The food and feeding habits of C.nigrodigitatus have been investigated by several workers. In Kainji lake, Ajayi (1972) found that the fish fed mainly on detritus, crustaceans and insect larvae. Fagade and Olaniyan (1973) reported that the food of this species in Lagos lagoon consisted of bivalves mainly Aloidis spp. and gastropod mainly Neritina spp. Other food items were diatoms, algae, ostracods, copepods and cladoceras. Ikusemiju and Olaniyan (1977) found that

the most important food item is gastropod Peckymelania bryonensis. All the investigators reported that C. nigrodigitatus is an omnivorous fish.

2.4 Reproduction and breeding behaviour

Fagade and Adebisi (1979) observed that C. nigrodigitatus in Asejire lake spawns between April and October with a peak in June to July. They estimated a fecundity range of 189 - 2884. Ezenwa (1981) reported that C. nigrodigitatus is a seasonal breeder and spawns sometimes in December in Badagry lagoon. He reported that the eggs are numerous with an average diameter of 2.5mm and adhesive in nature.

On the other species of Chrysichthys, Ajayi (1972) found that C. auratus breeds between June and October in Kainji lake, while Ikusemiju (1976) observed that C. walkeri in Lekki lagoon breeds in most part of the year from September to June with a peak in March.

On the spawning behaviour of C. nigrodigitatus, Ezenwa (1981) reported that the fish spawn in dark hollow cavities in sandy or muddy bottoms. Sivalingram

(1975) reported that the male incubates eggs in its mouth and the sides of the head become extended laterally forming a pouch-like structure and as a result, the snout assumes a semi-circular broad shape. The author further reported that the male parent does not appear to feed during this time. He observed loss in weight to an extent that the internal body structure is visible externally.

Apart from the breeding behaviour, most of the work on the reproduction of C. nigrodigitatus has been on the seasonal cycle in gonadal development. No attempt has been made to relate the gonadal growth to changes in visceral organs such as the liver and the body constituents (fat, protein, ash and water).

2.5 Reproductive cycles in fish: Gonado-somatic index (GSI), helpatosomatic index (HSI) and Condition (K)

Reproduction in most teleost fish is a cyclic phenomenon (Scott 1979). This cyclicity is ultimately imposed by the fact that environmental conditions tend to recur cyclically (Scott 1979). Most fish

species have a yearly cycle of reproduction and once they begin, they follow it until they die (Lagler et al; 1979). However, a few may reproduce at any time they get together (Lagler et al; 1979).

In the course of a typical reproduction, the gonads mature and the ova are fertilized. Sometimes associated with these central processes is a wide range of accessory activities such as migration, various forms of social behaviour e.g. hierarchy formation and territory establishment and courteship and in some species parental care (Scott 1979).

2.5.1 Gonadosomatic index (GSI)

The ultimate determinants of reproductive cycles are large changes in the weight of the gonads (Htun-Han, 1978; Delahunty and De Viaming 1980). These changes in gonad weight are usually reported in terms of gonadosomatic index (GSI). This expresses the gonad weight as a percentage of the whole body weight (Htun-Han 1978). The use of GSI as an indicator of gonadal development conceals the fact that

several physiologically discrete processes are taking place within the gonad (Scott 1974). One of such processes, as reported by Htun-Han (1978), is the deposition of large amounts of protein and lipid in the developing eggs and spermatozoa. Larson (1974) reported that part of these materials (protein and lipid) come directly from ingested food and a major proportion come from reserves of food deposited during the active feeding season in organs such as the liver and in the muscles. It is therefore reasonable to expect that weight of liver and muscle would reflect the accumulation and utilization of these reserves during gonadal maturation.

2.5.2 Condition factor.

The usual method of expressing changes in the weight of food reserves stored in the muscle is in the condition factor. It is defined as the ratio of the weight of the whole fish (without gonads) to the cube of its length (LeCren 1951). The changes in condition factor in several fishes have been ascribed to a depletion of reserves during gonad maturation

(Love 1983). Gupta (1974) stated that the condition of a fish is affected by its gonad weight and visceral weight, and that studying the condition factor of fish during different months of the year, the reproductive period of that fish and its duration could be traced. Scott (1974) observed that in the reproductive cycle of Mormyrus kannume forsk both males and females reached their maximum condition value prior to spawning, and it fell progressively throughout the spawning season. Jones (1970) reported that in turbot, S. maximus condition (K) is lowest after the fish has spawned and concluded that K is closely linked with reproductive cycle, Similar observation was made for dab Limanda limanda by Lee (1972).

2.5.3 Hepatosomatic index (HSI)

Changes in the liver weight of some fish have been correlated with changes in gonadal weight (Zahnd 1959 in Delahunty and De-Vlaming 1980; Krivobok, 1964 in Htun-Han 1978; Larson 1974; Wingfield and Grimm 1977; Wootton et al. 1978; and Smith 1990). The usual method of expressing liver weight is as the hepatosomatic index (HSI). This expresses the liver

weight as a percentage of the whole body weight of fish. Krivobok (1964) in Htun-Han (1978) has shown a direct correlation between liver weight and size of oocytes in Baltic herring, Clupea harengus membras. Htun-Han (1978) reported that in Limanda limanda there is an annual cyclical change in HSI. It begins to decrease during the spawning period, reaching its lowest point in the post spawning period; increasing in the resting period, which also coincides with the time of active feeding of the fish. The HSI reached its peak in the prespawning and early spawning periods. Larson (1974) in a study of liver weights of brook trout, Salvelinus fontinalis however observed a decrease in the weight of the liver in the prespawning season. He explained this to be due to the passage of materials from the liver to the gonads and concluded that weight changes in the liver plays an important role in gonad maturation. However, such correlation is not found in dab Limanda limanda (Htun-Han 1978), suggesting that the reserves in the liver are depleted during the process of yolk formation. Wingfield and Grimm (1977) showed that in the Irish sea plaice, Pleuronectes platessa HSI is highest in the prespawning period and

lowest in the post spawning period. In Pacific cod, Smith et al. (1990) reported that the highest liver index in the females coincided with maximum gonadal development, while in the males the highest liver index occurred just before the peak of spawning. Wootton et al; (1978) in females sticklebacks observed that the breeding season are periods of relative depletion from the liver and carcass.

2.6 Nutrient cycling during gonadal development.

Although reproductive cycles have been studied in the tropics, little information is available on nutrient cycling during gonadal growth. Shulman (1974) summarizing his early work on energy cycles in temperate marine fish noted that large variation in fat levels during the annual cycle are in marked contrast to the much smaller amplitude of protein cycle. He concluded that the dynamics of fat reserves is related to the magnitude and variability of food supply. Recently, the importance of lipid reserves for gonadal development has been shown (Wootton et al, 1978; Delahunty and De Viaming 1980). They reported that the reserve lipids are

utilized to provide material for the maturing gonads. Craig (1977) showed that both body lipid and protein are utilized during gonadal development in perch, Perce fluviatilis; however, more lipids are used than proteins. Shatunovskii and Novikou, (1975) quoted by Love (1983) observed that maturation of gonads in Gadus callarias involves the transfer of lipid from the liver, muscle or gut to the gonads, though, much more is used to supply energy than to produce yolk. They reported further that initial period of gonadal maturation is accompanied by an increase in both body and liver weights. However, as the gonad grows, its lipid requirements outstrip the now restricted intake, the body and the liver therefore suffer a sharp loss. Turuk, (1972) showed that there is an increase in liver lipid during the early ripening of the gonads of Gadus morhua; followed by a decrease of lipid at the maturation of the gonads. The differences in nutrient accumulation between sexes have been documented by some workers. Shevchenko (1972) reported that females of Haddock fish (Melanogrammus aeglefinus) concentrate on the accumulation of protein rather than lipid as they prepare for maturation, while

the males accumulate more lipid because their gonads need less protein and they expend more energy than the females in moving about the spawning grounds. Same observation was made for the males of Gadus callarias by Shatunovskii et al., (1975) citation in (Love 1983) and by inference for the male of Pollachius virens (Storozhuk, 1975; quoted in Love (1983). The differences in gonad size between sexes, resulting in a difference of lipid needs have been reported by some workers. Chepurnu and Tkachenko (1973) calculated that the total lipids in the gonads of male Gobius melanostomus are almost ten times less than that of the females, so they concluded that little is required to be taken from the depots during maturation. Love (1983) showed that female fish carry greater reserves in their livers. Shevchenko (1972) reported that the lipid of male Melanogrammus aeglefinus increases four-fold during feeding period while that of the females increase only 1.5 times. However, Valtonen (1974) quoting other authors showed that in "many teleosts" the liver is smaller in males preparing to spawn than in females which must produce yolk. A similar

observation have been made on Melanogrammus aeglefinus by Campbell and Love (1978). Generally, the reserve lipids are shown to increase after spawning more in the female than in the males (Ziecik and Nodzniski 1964 in Pleuronectes flesus; Ke et al, (1969); in Mallotus villosus and Turuk (1972) in Gadus morthua.

On the utilization of lipids, many workers observed that the utilization of lipids differs between sexes. Shatunovskii and Novikov (1971) found that more lipid is removed from the muscle of female Salmo trutta than males as maturation advances, while Shchepkin (1971) demonstrated a somewhat greater reduction in the liver lipid of female Scorpaena porcus. Bogovavlenskaya and Velltishcheva (1972) in Love (1983) reported that Gadus callarias females withdraw mostly lipid from their bodies while males withdraw mostly glycogen from the liver. Very little information is available on the changes in the ash content of fish during gonadal development. However, Wootton et al, (1978) in the female stickle-backs (Gasterosteus aculeatus) and Wootton and Mills (1979) in female minnows Phoxinus phoxinus (L) reported

that the ash content of the carcass shows a marked seasonal fluctuation and increase during the breeding season.

Hails (1983) reported that the levels of protein remain fairly constant during the gonadal developments of tropical anabantid, Trichogaster pectoralis. Shul'man (1974) concluded that the nutrient cycling especially lipids, during gonadal development serves as an index for spawning preparation; and this can therefore be used to determine the state of the fish during its readiness to spawning.

2.7 Control of reproduction through the manipulation of environmental condition

Ovulation can lead to successful reproduction (spawning) only if critical external factors are appropriate (Stancey 1985). Woynarovich and Horvath (1980) reported that it is possible to stimulate spawning by simulation of suitable environmental stimuli. This method according to Scott (1979) offers economically viable alternatives to hormonal intervention by man, and it makes possible the mass rearing of

eggs and larvae in a well protected condition (Woynarovich and Horvath 1980).

Surprisingly, little is known of the details of how environmental cues regulate the occurrence of ovulation and spawning in teleosts. However, Lasker (1974) reported that acute temperature change can trigger spawning behaviour in some fish. Yamamoto et al, (1966) observed that increasing water temperature from 14°C to 20°C at any time of the year can induce ovulation within a day in goldfish. Stancey et al, (1979) reported that goldfish ovulate spontaneously even in cold water if they are exposed to aquatic vegetation (the normal spawning substrate). Although, warming alone is sufficient to trigger ovulation in some females, the proportion responding increases significantly, if warming is combined with exposure to vegetation (Stancey 1985). Bruton (1979) quoted by Stancey (1985) observed that a rise in water level triggers spawning behaviour in Clarias gariepinus.

The importance of spawning substrate in the regulation of ovulation/spawning according to Stancey (1985) is likely to be influenced by specificity of substrate requirement. He reported that absence of appropriate

Substrate inhibits ovulation whereas exposure to appropriate substrate can rapidly induce ovulation. Woynarovich and Horvath (1980) reported that spawning receptacles like milk cans, or oil barrels placed in a hiding place stimulated spawning in channel catfish. Clay, plastic or cement concrete pipes of large diameter (20 - 25cm) can be used to stimulate spawning in some other catfishes like Clarias batrachus (Woynarovich and Horvath 1980).

Visual and chemical stimuli can increase spawning frequency in females of some species (Liley 1988, 1982). Kramer (1972) found that in blue gourami Trichogaster trichopterus, ovulation is rapidly induced by brief exposure to a nest-building male. In Brachydanio rerio, males and females are known to remain together, throughout the breeding season. Eaton and Farley (1974) in Paul (1978) reported that a brief exposure of the female of this species to a male can induce ovulation the following day. Chen and Martinich, (1975) observed that in zebrafish Brachydanio rerio, ovulation can be stimulated by water obtained from males and inhibition of ovulation can occur by water from

crowded aquaria, indicating that Brachydanio sp. respond both to stimulatory pheromones and inhibitory metabolites.

2.8 Development of fish eggs and larvae

Once the fish has been induced to spawn and the eggs are fertilized the fertilized eggs start to develop. In the tropics, the process of egg development is usually very fast. It involves a complicated chain of events and it is very difficult to identify as many developmental stages as found in cold water species (Lagler et al; 1977). However, the following distinguishable stages have been identified; swelling stage, first cleavage, 4-cell-stage, 8-cell-stage, early morula stage, later morula stage, the blastula, gastula, the closing of the blastopore and the embryonic developmental stages (Woynarovich and Horvath 1980).

The newly hatched larva according to Blaxter (1969) in Hoar and Randall (1969) is usually transparent with some pigment spots of unknown function. Yolk sac is usually present. Notochord and Myotomes are

very distinct. The mouth, jaws, guts, gills and air bladder among other important organs have not yet appeared. But it is known that the heart functions just before hatching. The blood is colourless in the majority of species. Pigmentation of the eye is visible but the eye is not functioning at hatching. Very little is known about other organs of the body such as the gonads and endocrine glands. It is known that the kidney is usually pronephric with very few glomeruli (Blaxter 1969).

Generally, three distinct stages are described for most warm water fish. These stages are:

(1) The prolarval or non-feeding larva or the yolk sac larva.

(2) The feeding larva or the swim-up larva.

(3) The advanced fry (Woynarovich and Horvath 1980, Viveen 1985).

The period immediately after hatching and just before the start of external feeding is termed prolarval or yolk sac or non-feeding larva.

The swim-up or feeding larva stage begins when the larva fills up its air bladder with air, begins to swim, and starts to eat external food.

The advanced fry stage, is when the fish has assumed the full shape of the adult fish (Viveen et al, 1986).

2.9 Natural and artificial food for fish larvae

Most fish fry are either omnivores or carnivores depending on plankton and other food particles in their environment (Stickney, 1972; Bone and Marshall 1986). Bone and Marshall (1986) reported that the larvae of flatfish and mackerel fed mainly on copepods in their marine environment. In the freshwater environment the larval fish fed mainly on cladocerans and rotifers. Ogungbonna (1986) quoting Jocque (1975) reported that cladocerans, Cyclops phytoplankton algae and protozoa are the dominant food items of 4-day old fry of Clarias gariepinus. Further, Ogungbonna (1986) reported that the stomach content of 20cm fry of Clarias gariepinus from lake Sibaya includes mainly of larval Caridina nilotica and Chironomidae.

On the feeding behaviour, Wegihs and Moser (1981) in Pitcher and Hart (1982) reported that almost all teleost larvae are found to be visual feeders at initial stages of exogenous feeding. They snap up food particles one by one

hunting rather than seiving. The reason for this behaviour according to the authors might be due to their poor olfactory development. Hirano (1969) and Mito et al, (1969), quoted by Lee et al. (1981) reported that rotifer Brachious plicatilus is commonly used as food for marine larval fish. Sampson (1955) in Applegate (1981) stated that microcrustaceans from waste water stabilization ponds are excellent as first food for tropical larval fish. Applegate (1981) found that immature M. brachiata (Cyclops) appeared to be adequate size to feed muskellunge fry Esox masquinongy during the alimentary canal development. Kenneth et.al, (1986) reported that cyclopoid, copepod and cladocerans preyed on larva of walleyes Stizos tedion vitreum vitreum fish. They found that Artemia sp. may be the best choice of first food for the larvae because brine shrimp support high growth and survival of walleyes and do not prey on the larvae. Vander-wind (1979) and Woynarovich and Horvath (1980) suggested that the most suitable food for larval fish as to size and quality is rotifers, followed by Artemia salina or Artemia naupli. On the contrary, Heltler (1981) reported that rotifers are not essential in the feeding of larvae, rather

larvae could be fed on sifted wild plankton (64 to 202 um) as this will give larval fish the opportunity to select their food. This method of feeding gave 50% survival on Atlantic Menhaden larvae (Heitler 1981), and 57.26% survival was recorded for Clarias gariepinus fed on zooplankton (Bamimore 1989). Lannan et al, (1983) reported that the larvae of most fish feed initially on zooplankton. Smaller phytoplankton and larger zooplankton had been reported to be important first food for some species (Roy and Gupta (1973); Parameswaran et al, (1974); Lasker (1975); Arnemo et al, 1980). Table 2 shows the first food of some selected fish species.

2.10 Utilization of plankton by larval and fry fish

Zooplankton are high in protein and essential amino acids (Sadykhov et al,1975) and are easily digested. Gorbunova and Lipskaya 1975 in Lannan et al (1983) and Stephen (1976), reported that fry normally consume zooplankton 40 to 80 per cent of their body weight daily, assimilating from 89 to 98% of the ingested food (Miliyenko 1979; Ogino and Watanabe 1978; citation in Lannan et al, 1983). Spectorova et al,

Table 2 - First food of various cultured and non-cultured fish species

Fish species	Fish age/size	Food item	Source
1. Tilapia nilotica	Fry	Rotifers, copepods detritus, aufwuchs hydracarines	Moriarty et al, (1973)
2. Cyprinus carpio	4 - 5days/6 - 8mm	Rotifers (50 - 150u)	Tarma and Horvath (1976)
3. Catta catta	Larva and young fry (1 - 15days)	Phytoplankton, Cladocera, rotifers Copepods	Chakrabarty et al, (1973)
4. Puntinus pulchellus	18 - 23mm	Zooplankton	David and Rahman (1975)
5. Sea bream Archosargus rhombiodalis	3days	Nauplii and Copepodites and copepods 100u	Stephen (1976)
6. Green back gray millet Liza subvirdis	12mm	Zooplankton	Chan and Chua (1979)
7. Black sea turbot (Scophthalmus maeoticus)	--	Rotifers	Spectorova et al, (1974)
8. Clarias gariepinus	5days	Zooplankton	Bamimore (1989)

(1974) observed that larvae and fry usually feed throughout the day, digesting a food batch in three to four hours. The rate of digestion varies; for instance, Cladocera are digested much more rapidly than copepods. This relative rate of digestion, according to Gannon (1976), may result in erroneous estimates of food selectivity due to fast disappearance of certain species in the gut.

The oustanding qualities of live plankton (movement, size, protein content, palatability, digestibility) according to Lannan et al, (1983) are impossible to match with artificial ration. Although several varieties of artificial feeds have been developed for larval fish to replace natural foods (Van-der wind 1979; Dabrowski et al, 1978; Krise and Meade 1986; and Bamimore 1989), all have resulted in either increased mortality (due to poor acceptability by fry) or decreased growth rate(due to nutritionally incomplete diets when compared to live plankton (Lannan et al, 1983). The authors concluded that it is nearly impossible to rear larvae and fry entirely on an artificial ration. However, Chow (1981) recorded good survival rate of fry with the use of micro-encapsulated egg diets - an artificial diet prepared from chicken eggs,

enriched with some vitamins and minerals.

2.11 Causes and prevention of fish larval motality

One of the problems responsible for the mass mortality of fish larvae is lack of adequate and suitable food. The wrong size of food are usually given to larval fish. The size of the food might be too large or the mouth of the larvae might be too small, eventually the larvae are unable to feed and consequently die of starvation (Van der Wind, 1979; Woynarovich and Horvath 1980). Woynarovich and Horvath (1980) suggested that larval fish could be fed on very small live organisms along with artificial diet. The artificial diet must be in powdery form, finely sifted and must be balanced in basic food components. Also the food must be provided in adequate quantities to ensure that larvae take sufficient quantity of food for growth. They recommended the use of *Artemia salina* larvae, as this food is small enough for the larval fish to ingest and is balanced in essential nutrients.

The taste organs of the developing larvae are not yet properly developed and the larvae must therefore

detect its food with the aid of its eyes. If the rearing device is too dark, or too bright the fry will not be able to detect its food (Blaxter 1962; Shelboure 1965; and Woynarovich and Horvath 1980), and this could lead to starvation and death of the fish. The larvae will therefore need an illuminated surrounding for easy detection of food.

Blaxter (1962), suggested the use of black tank for the culture of larval fish. Shelboure (1965), working on larvae of Plaice and Blaxter (1962), working on the larvae of herring, reported that larvae could distinguish food particles easily in black rearing tanks.

Predation is another cause of fish mortality; insect larvae, cladocerans, copepods and other carnivorous zooplankton consume fish larvae or damage their skin badly (Woynarovich and Horvath 1980). Kenneth and Lien (1986) reported that copepods and cladocerans preyed on walleye larvae and this resulted in the mass loss of the larvae. It is known that mortality from predation of fish larvae increases as the concentration of cyclopoids increases (Davis 1959 quoted by Hokanson and Lien (1986), Fabian 1960

and Suckhanova 1968). Densities of copepods as low as 100/l are known to cause mass loss of fish larvae within a short period (Woynarovich and Horvath 1980; Kenneth and Lien 1986). The macropredators such as worms, fishes, insects must be kept away from the larval rearing device. The micropredators such as cladoceran and copepods can be killed by treating the culture-water with organic phosphoric acid ester according to the recommended dosage of Woynarovich and Horvath 1980). This chemical will kill the predators but not the larval fish or rotifers which are excellent food for the larvae (Woynarovich and Horvath 1980).

The exposure of larval fish to sunlight has also resulted in mass kill. This is because most fish larvae have very sparse or no pigmentation; they do not have protection against ultraviolet rays of the sun. This particular case of larval mortality has been observed in pike perch Stizotedio lucioperia and Colossoma occulus (Woynarovich and Horvath 1980).

Oxygen deficiency as a result of overstocking, drastic changes in temperature, competition, toxic wastes etc. can all result in larval mortality (Woynarovich and Horvath 1980; Li and Mathias 1982,

Krise and Meade 1986). These can however, be prevented by not overstocking the rearing device. The stocking density advised by Woynarovich and Horvath (1980) is 1 larva of fish/cm^3 and that water should be well aerated. Live food should be fed to the larval fish in concentrated form with very little of its culture-water so that the organic matter in the water may not cause oxygen depletion. The larvae should be fed every one-half to one hour and the rearing device should be cleansed daily (Woynarovich and Horvath 1980).

Diseases and parasites which are known to claim many lives of larval fish could be prevented by feeding larvae with adequate amount of both natural and balanced artificial diet. Healthy fish cannot be seriously harmed by parasites whereas, the weak and undernourished fish cannot resist parasitic infection. Another important way to prevent infection is to ensure that adult fish which may be habouring parasites are kept away from the young fish. Another preventive way is to clean the rearing device with disinfectant such as quick lime, chloride lime or formalin (Woynarovich and Horvath 1980).

The problem of cannibalism where larger fry eats smaller ones has also resulted in fish mortality (Cuff 1977, 1980; Li and Mathias 1982). Li and Mathias (1982) reported that cannibalism among larvae is grestest during the first 20 days of hatching. Cuff (1977) observed that greatest food availability significantly reduced cannibalism among walleyes larvae. Feeding larvae with food of high energy content may also suppress cannibalism (Kenneth and Lien 1986). Cannibalism can also be suppressed by feeding larvae with very small food particles, so that the very small larvae and the big ones are given equal chance to feed.

2.12 Nutrient requirement of fish

The practice of fish culture under intensive or semi-intensive systems called for the development of artificial diets to meet the nutritional needs of the fish. Fish require certain amount of nutrients for growth, body maintenance, reproduction and other physiological processes (Dupree and Hunder, 1984). These nutrients include proteins carbohydrates, lipids, vitamins and minerals. Protein is the major nutrient required for growth (Winfree

and Stickney, 1981); it is necessary for body maintenance, repletion of worn out cells and formation of new proteins (Cowey and Sergent 1972). It is the largest and most expensive constituent of fish diet (Cowey and Sergent 1972). It is therefore the most critical nutrient for fish and it needs to be estimated in terms of its requirement for every culturable fish species and at different stages of growth for a profitable fish culture. .

2.13 Protein requirement of fish

The protein requirement of fish is defined as the protein content in diet which gives maximum growth, maximum economic profit and maximum protein deposition (Erland *et al* 1979 cited in Ugwu 1984). The proportion of protein required by fish varies from species to species (Cruz *et al*, 1977). This has been attributed to food and feeding habits of different fish species. Some fish are piscivorous, others are herbivorous, carnivorous or omnivorous. The optimal protein requirements for various fish species have been determined by several workers Table 3 shows the quantitative dietary protein

Table 3 - Quantitative dietary protein

Species	Fry to fingerlings % protein	Fingerlings to sub-adult % protein	Adults and broodfish % protein	Source
Eel	50 - 60	45 - 50	-	Dupree (1976)
Channel catfish	35 - 40	25 - 36	28 - 32	" "
Large mouth bass	40	40	35	" "
Common carp	43 - 47	37 - 42	28 - 32	" "
Stripped bass	40	40	35	" "
Trout and Salmon	50	35 - 40	30 - 32	" "
Sarotherodon galilaeus	35	25	25	Odimayo (1986)
Clarias gariepinus	30	34	40	Ayinla (1985)
Red sea bream	45 - 48	43 - 48	-	NRC (1977)

requirements of some selected fish species at different stages of life cycles.

The differences in protein requirement recorded for different fish species might be due to many factors. Among these are the level of protein intake (Cowey et al, 1972); Protein digestibility, protein energy ratio (Combs et al, 1962; Fowler et al, 1964); Sanility (Zeitoun et al, 1974); water temperature (Delong et al, 1958); fish size (Satia 1974); Pillay 1980); quality of protein (Cowey 1974, Pillay 1980); natural foods present in fish environment (Pillay 1980, Aboaba 1984); feeding rate of fish; environmental stresses such as stocking density; and dissolved oxygen. Others are physiological state of the fish (Cowey et al, 1974); formulation of basal diets and experimental duration (Shiau et al, 1987).

2.14 Amino acid requirement

The utilization of protein content in fish diet is dependent on its amino acid constituents and availability. Cowey and sergent (1972) found that the more closely a food protein meets the need of an animal for essential amino acids, the greater the

utilization. Generally, 10 essential amino acids are required by fish; these are arginine, histidine, isoleucine, leusine, lysine, methionine, phenylalanine, threonine, tryptophan and valine (Halver 1957). The non-essential amino acids are not necessary for the body protein synthesis, the essential amino acids serve as precursors for their synthesis (Halver 1957).

Quantitative dietary requirements for all the 10 essential amino acids have been established for only four fish species namely common carp Cyprinus carpio, Japanese eel Anguilla japonica, Channel catfish Ictalurus punctatus, and Chinook salmon (Oncorhyncus tshawytscha) (Tacon and Cowey 1985). Table 4 summarises the quantitave essential amino acid requirements of some fish species.

Mertz (1972) reported that if any one of the essential amino acid is inadequately supplied in the diet, the utilization of the other amino of acids is correspondingly reduced, and if any of the amino acids is present in surplus, the excess is not stored as some vitamins but it is quickly destroyed or goes through other metabolic pathways.

Table - 4 - Quantitative essential amino acids requirements of some selected fish species

Species	Arginine %	Histidine %	Isoleucine %	Leucine %	Lysine %	methionine %	Phenylanine %	Threonine %	Tryptophan %	Valine %	References
Cyprinus carpio	3.3	2.1	2.5	3.3	5.7	2.1	3.4	3.9	0.8	3.6	Nose (1979)
Ictalurus punctatus	4.29	1.54	2.58	3.5	5.1	1.34	2.04	2.21	0.5	2.96	N.R.C (1983)
Anguilla japonica	3.9	1.60	3.6	4.8	4.8	2.1	2.90	3.6	1.0	3.6	Nose, (1979)
Salmo gairaneri	4.0	-	-	-	5.7	-	-	-	-	-	Kim et al., (1983).
Oreochromis mossambicus	4.0	-	-	-	4.1	1.33	-	-	-	-	Jackson et al. (1982).
O.Kitsutch	6.0	1.7	-	-	4.3	-	-	-	0.5	-	Klein & Halver, (1970).

2.15 Lipid requirement

Lipids or fats contain twice the amount of calories per gram of proteins or carbohydrates, thus contributing greatly to the energy levels of fish diets even when present in relatively low quantities (Stickney, 1977). Lipid can therefore provide some sparing actions for protein. Thus lipid can be used for maintenance and metabolism and protein will be freed for growth. However, the extent to which lipid can be used in sparing protein for growth is not yet determined but it is known that diets containing 8% lipid led to high levels of protein deposition than diets containing 4% lipid (Stickney, 1977). He reported further that increase in dietary lipid up to 16% did not enhance protein deposition in fish, and concluded that too much lipid in the diet could lead to certain nutritional diseases such as fatty livers. Watanable & Takashimo (1977), Takeuchi et al, (1978) suggested that high levels of lipid may alter the carcass composition by deposition of excessive lipid. They found that increase in the percentage of dietary lipids increase the whole body lipid but reduces the percentage of body protein.

2.16 Carbohydrate requirement

Carbohydrates are the cheapest source of food energy (Lovell 1979b). They are known to be utilized by various fishes, but only limited information is available on their digestibility and metabolism (Wilson 1979). Cowey et al, (1972) found that fish can grow very well on diets devoid of carbohydrate. Phillips et al, (1966) reported that carbohydrates may function as immediate energy source for fish, and can act as a quick energy reserve, stored as glycogen in the liver and muscle; it can also stand as a long-term energy reserve if converted to fat in the body.

Studies on carnivorous salmonids have shown that high levels of carbohydrate resulted in poor growth, high glycogen liver and increased mortality (Phillip et al, 1966; Austreng et al, 1977). However, Begot (1979) fed salmonids with high levels of carbohydrates without any abnormal signs.

Many workers have looked into the protein-sparing action of carbohydrates in fish diets (Lee et al, 1973 for salmon; Cowey et al, 1975 for turbot, and Tiemier et al, 1965 for channel catfish). They

reportedthat there was increase in growth rate, when fish were fed on a series of diets with constant protein content (37.5%) but with increasing levels of carbohydrates up to a level of 20%, suggesting that less protein in the diet was used for energy purposes. Carbohydrates are therefore included in formulated fish diets to serve as a low cost source of energy to spare dietary protein for growth. The requirements of dietary carbohydrate have not been thoroughly investigated for warm water species. But it appears that they are able to use starch better than the cold-water fishes (Lovell 1979a).

2.17 Mineral requirements

Fish utilize minerals for structural, biochemical and physiological functions (Underwood 1977). In addition, minerals are used to maintain the osmotic balance between body fluid and water (Phillip and Podoliak, 1957). Twenty-two different types of minerals are required by fish, seven of which are known to be essential. These are calcium, phosphorus, potassium, sodium, chlorine, magnessium and sulphur. The remaining fiften are just required in trace amount and

are collectively referred to as trace elements (Lall 1979). Most of the essential minerals may be obtained from water environment by exchange across the gills and skin (Lall 1979). Certain minerals which are present in very low concentration in the water are obtained from feed sources (Phillips et al, 1957; Phillips et al, 1963). Diets containing high levels of animal protein may not require supplemental organic phosphorus as phosphate (Phillip et al, 1957). Lovell (1977) reported that natural feedstuffs are usually adequate in potassium, magnesium sodium and chloride for normal growth of animals unless there is a high rate of mineral loss. These minerals are, therefore, available in sufficient quantity in practical feed diets without mineral supplementation. However, fish feeding low in animal products may be deficient in trace minerals. The mineral supplement recommended for channel catfish is shown in Table 5.

Table 5 - Mineral supplement recommended for channel catfish (After Lovell, 1977).

Minerals	Amount recommended in mg/kg
Mn	115
I	2.8
Cu	4.3
2n	88
Fe	44
Co	0.05

Chow and Schell (1980) recommended arbitrary levels that are based upon land animal requirements.

2.18 Vitamin requirements

The quantitative requirement of vitamins according to Dupree (1966) is based on the minimum level that will support growth of fish without defiency symptoms or mortality. Most fish have requirements for eleven water-soluble vitamins and at least three or four fat-soluble

vitamins (Halver 1979). Dupree (1966) reported that many of the vitamins used in fish diets can be damaged due to improper handling or storage. It was observed that vitamin B_{12} was lost when prepared under alkaline conditions or in the presence of sulphide riboflavin. Vitamin B_6 (Pyridoxine) was lost when exposed to sunlight and air. It must therefore be protected from sunlight and air. Vitamin E is sensitive to oxidation, therefore, a supplemental antioxidants should be added to fish feeds. It was finally concluded that prepared diets should be utilized fairly rapidly as vitamin activity is easily disrupted.

2.19 Growth and factors affecting it

The growth of fish is the difference between the energy income and energy expenditure (Ursin 1979), the energy income being provided by food. It is expressed in the equation:

$C = F+R+U+P+G$ (Reay 1979).

where C = Consumption or food intake

F = Faeces

R = Metabolism

U = Excreta

p = Body growth

G = Gonad growth

P (body growth) = C - (F+R+U+G). Thus, energy for metabolism, excretion and gonad development must be satisfied before energy is available for growth (Bret, 1976; Reay 1979; and Smith 1980). Approximately 60 per cent of energy in fish is utilized for maintenance and the remaining 40 per cent is used for growth (Hepher 1975).

Generally, growth in fish depends on the quantity and quality of food supply (Bond 1979); the feed intake (Elliot 1975a); fish appetite (Brett, 1971; Elliot (1975b), stocking density (Andrews et al, 1970), oxygen level (Andrews et al, 1971; Smith 1980); temperature (Andrews and Stickney, 1982); fish size (Page and Andrews, 1973); genetic ability of the fish to seek and find food, its assimilating capacity, vital activities and sex (Love 1976, Bond, 1979).

Body weight gain is dependent on the level of protein in diets, it is used as a measure of growth in various fish species. These include common carp Cyprinus carpio (Ogino and Saito 1970); Japanese eel Anguilla japonica (Nose and Arai 1972); Rainbow trout,

Salmo gairdneri (Satia, 1974 Zeitoun et al, 1973); Grass carp (Dabrowski 1977); Sarotherodon mossambicus (Jauncey 1982; Jackson et al, 1982); Oreochromis niloticus Shiwa et.al: 1987; and Otubusin 1987); Clarias gariepinus; (Arowosoge 1987, and Ayinla 1988). Generally, increase in growth rate is associated with increase in protein level of the diet (Poston 1975 and Dahlgren 1979). However, gradual growth retardation has been observed in some fish after certain level of protein inclusion (Jauncey 1982; Jackson et al, 1982 and Otubusin 1987).

Apart from body weight gain, other indices of food utilization are food conversion ratio (FCR) and food conversion efficiency (FCE) (Utne 1979). Food conversion ratio is usually expressed in terms of dry weight of food: wet weight of fish, while the food conversion efficiency is the percentage of the inverse of FCR. FCR assumes that all food has been consumed and that same units of measurement are used (Reay 1979).

2.20 Chemical composition of fish body

The chemical body composition of fish is influenced by the quality and quantity of fish diets (Love, 1970).

Dabrowski (1977) reported that fish fed on a non-protein diet showed a lower body protein content, higher body fat and ash than those fed on protein diets. Cowey et al, (1972); Dabrowski (1977); Jobling and Wandsivik (1983); observed that flat content of fish increase with increasing dietary protein levels while other body components like protein, ash, remain unchange. However, in some fish species the body protein content increase while body fat content decrease with increasing dietary protein level (Luquent and Sabant 1973, for gilt-head bream; Cowey et al, 1972 for plaice; and Ogino et al, 1976, for carp). Nose and Arai (1972) did not notice any defined trend of relationship in the body protein content of eels when fed on different levels of dietary protein.

Other factors affecting body composition are body size (Parker and Vanstone 1966, Ehrlick 1972, 1974); age of fish (Denton and Yousef 1976); environmental factors (Perera and De Silva 1978); sex of fish, stages of gonadal maturation; nutritional status, starvation and stress (Love 1970).

There is a striking relationship between lipids and water content of fish (Love 1970). An increase in one leads to a decrease in the other so that the sum of both parameters is approximately constant. The fat water relationship have been shown for a number of species, for Sarotherodon mossambicus, Arctic Charr (Salvelinus alpinus) Jobling and Wandsvik(1983) for rainbow trout Salmon gairdneri, Delton and Yousef (1976) and others.

Chapter 3

3.0 Materials and methods

3.1 Reproduction in Chrysichthys nigrodigitatus

3.1.2 Collection and laboratory procedures

C. nigrodigitatus specimens were collected on first week of every month from Asejire lake by means of gill nets and traps. The fish were transported in ice-chest to the laboratory for analysis.

In the laboratory, all specimens were individually blotted dry, labelled and measured for total length, standard length (to the nearest mm), and weighed (to the nearest 0.01g). Each fish was then dissected to expose the gonads. The colour and texture of the gonads were observed and maturity stage was assigned following the classification of Nikolsky (1963). Gonads and liver were dissected free from the body cavity and weighed separately to the nearest 0.01g.

3.1.3 Fecundity determination

Fecundity was determined gravimetrically by weighing a sub-sample approximately 0.1g. The oocytes

in these sub-samples were counted and fecundity was estimated by the ratio of sub-sample weight to the total weight of the ovaries.

Regression analysis was performed to determine fecundity relative to length, weight of fish and the weight of ovaries.

3.1.4 Determination of gonado-somatic index (GSI), hepatosomatic index (HSI) and condition factor(K)

Data on body weight, gonad weight and liver weight were used to calculate the gonadosomatic index (GSI), hepatosomatic index (HSI) and condition factor (K) using the formulae:

$$GSI = \frac{\text{Gonad weight}}{\text{Whole body weight}} \times 100$$

$$HSI = \frac{\text{Liver weight}}{\text{Whole body weight}} \times 100$$

$$K = \frac{\text{Body weight} - \text{gonad weight}}{\text{Length}^3} \times 100$$

(Htun-Han 1978).

Each of these parameters was computed for each fish and an average value obtained for each month of the year.

3.1.5 Proximate analyses of the gonads, livers and carcass of C. nigrodigitatus

Monthly samples of gonads, liver and carcasses were pooled separately according to sex , and maturity stages of the gonads. These were dried in an oven at 70°C to a constant weight. The samples were homogenized and then analysed for protein, lipid, ash and crude fibre, using the methods of A.O.A.C (1980) as described in section 3.5.0. The carbohydrate content of the samples was estimated by 'difference'.

The proximate analysis of the testes was not determined because of its relatively small size.

3.1.6 Sex-ratio

The sex ratio was calculated by expressing the respective numbers of males and females as a percentage of the total number of fish examined.

3.1.7 Size at maturity

Size at maturity was determined as the length at which gonad stage IV (Nikolsky 1963) was observed in an appreciable (<50%) number of specimens.

3.1.8 Reproductive cycle

The seasonal changes in gonad weight in relation to body weight expressed as gonadosomatic index (GSI) was used to study the reproductive cycle.

3.2 Semi-artificial spawning of C. nigrodigitatus

3.2.1 Selection of spawners and preparation for spawning:

Spawners were collected from Asejire lake. The criteria for the selection of the female breeders were based on the weight, colour, swelling of cloacal region, protusion of the abdomen and extrusion of eggs upon slight pressure of the abdomen. The male spawners were selected on the basis of weight, colour of body, shape of the head, colour of the genital papilla and extrusion of milt following slight pressure of the abdomen. Then a female and a male of similar weight were chosen to form a couple. Each couple was placed in a confinement made from bamboo tube. The length of the bamboo was 70 cm and 11.25 cm in diameter. The female fish was first put inside the bamboo tube with the head facing the upper end of the tube, while the male fish was later introduced into

the bamboo tube with the head facing the lower end of the tube so that the genital papillae of the two fish were facing each other (see figures 1 to 3).
The two openings of the bamboo were made in such a way that fish can easily enter through it but cannot rotate to get out of it. For safety, the two openings were tied with nylon net. The bamboo was gently placed in the littoral zone of Asejire water and anchored to a substratum. Water was passing freely in and out of the bamboo confinement.

Another set of couple in a confinement was put inside a concrete tank located in front of hydrobiology and fisheries laboratory of the University of Ibadan. Dechlorinated tap water was introduced into the tanks before the bamboo was placed in it.

The Asejire water and the dechlorinated tap water in the concrete tank were monitored for the dissolved oxygen concentration, pH and temperature using the methods described in section 3.4.5. The fish in the bamboo confinements were checked for spawning every twenty-four hour.

DIAGRAMATIC ILLUSTRATION OF THE SPAWNING PROCESS IN STAGES

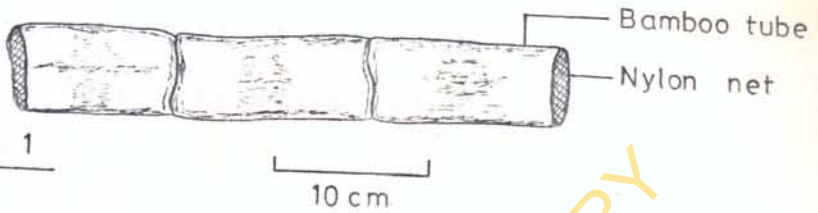

Fig. 1 : Bamboo tube

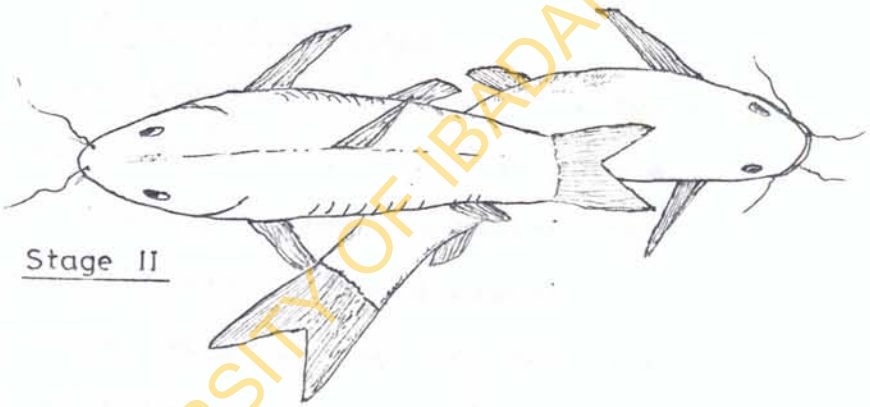

Fig. 2 : Positioning of the male and female of C. nigrodigitatus inside the bamboo tube

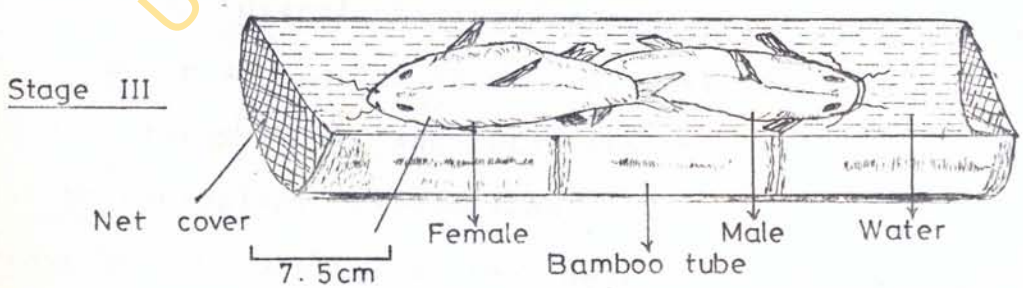

Fig. 3 : Cross-sectional view of the male and female of C. nigrodigitatus inside the bamboo tube

3.2.2 Collection and estimation of spawned eggs

After spawning, weight of the spawners were taken, and the tertilized eggs were collected and brought back to the laboratory in jars of water. The number of eggs released after spawning was estimated by the difference in the weight of spawner before and after spawning multiply by X. Where X = number of eggs present in 1g of eggs.

3.2.3 Incubation and hatching of eggs

In the laboratory, eggs were incubated in well aerated static tap-water which had been allowed to stand for 48 hours in aquaria tanks. The incubation temperature, pH and dissolved oxygen concentration were monitored using the methods described in section 3.4.5. The hatching time was noted and the number of hatched eggs were estimated volumetrically.

3.2.4 Morphological observation and larval development

5 - 8 samples of the larvae were removed every 24 hour for yolk sac and total length measurements and for morphological observations. Larval length was measured from the tip of the upper jaw to the distal extremity of the 'tail', using a graph paper calibrated in millimeters. The morphological features of

the developing larvae were observed under a binocular microscope fitted with an eyepiece of graticule reading to an accuracy of 0.02mm. Larvae were weighed on a Mettler balance to the nearest 0.0001g. The specimens were preserved in labelled bottles containing formol-acetic alcohol (F.A.A.) (Kahle's fluid).

3.3 Exogenous feeding trials of larvae

3.3.1 Diet preparation:

3 artificial diets were formulated to contain 40%, 35% and 30% crude protein levels. Feed ingredients were weighed out according to the formulation (see feed formulation in Table 6). The ingredients were milled together using a laboratory hammer mill. The products were sifted and mixed in an electric mixer for homogeneity. The diets were then stored in air-tight containers at room temperature.

3.3.2 Plankton production

An outdoor concrete tank was used for the culture of plankton. About 5gms of the N-P-K fertilizer was added to 459 litres of water.

The application rate was based on the recommendation of Charkroff (1976). A rich culture of plankton developed within 24 - 48 hrs of application. Using a 64 micron plankton net, a mixed culture of live plankton was collected from the tank. The predominant onces were rotifers, cladocerans and copepods. These were fed to the fish fry.

3.3.3 Feeding trials of the larvae of C. nigrodigitatus

The feeding trials were conducted in 8 aquaria inside the laboratory. The aquaria were supplied with dechlorinated tap water. The larval fish were divided into four dietary groups viz:- Group A, B, C, D; each group was fed 40%, 35%, 30% crude protein diets and cultured plankton respectively. Each aquarium tank was stocked with 50 fish fry. All fish were weighed, and measured before stocking. They were fed four times daily at 10% of their total body weight. They were reweighed and measured every week. Dead fry was checked twice daily (Morning and evening) and removed by suphoning, counted and recorded. Percentage survival was calculated daily.

3.3.4 Water quality management

The dissolved oxygen concentration, pH and temperature were monitored daily using the methods described in section 3.4.5. Water in all tanks was changed daily and aerated.

3.4.0 Growth responses and nutrient utilization of the fingerlings, juveniles and adults of C. nigrodigitatus to varying dietary protein levels

3.4.1 Collection and acclimation of experimental fish

The experimental fish were collected from Asejire lake by the use of traps and gill nets, and they were transported live in a Coleman's ice-chest to the concrete tanks located outside the laboratory. The fish were allowed to acclimate for 15 days, during which they were trained to feed on pelleted feeds obtained from Nigerian Institute of Oceanography and Marine Research (NIOMR) at 9.00 a.m. and 5.00 p.m. daily.

3.4.2 Fish feed formulation and preparation

Fish feed with protein levels ranging from 15% to 40% were formulated using the Pearson's square method as described by Gohl (1985). Prior to the formulation of the diets, all feed ingredients were subjected to proximate analysis to determine their crude protein content. The choice of feed ingredients was based on availability, cost, protein, energy, vitamin and mineral contents. The ingredients were fish meal, groundnut cake, maize, rice bran, palm oil, bone meal, oyster shell, sodium chloride (table salt) and vitamin premix.

Groundnut cake and fish meal were added as the primary protein source in a ratio of 2.5 : 1 while maize and rice bran were added as energy sources, in a ratio of 2:1 Palm-oil served as a good source of energy, it was included at 5% level in all the diets. Bone meal and oyster shell were added as mineral sources at 2.5% and 0.5% respectively in all the diets. Sodium chloride was also added as mineral source and for palatability at 0.25% in all the diets. All diets were fortified with vitamin premix at 0.60% inclusion

Table 6 - Gross Composition (%) of the experimental diets

Ingredients	15% crude (CP) protein	20% CP	25% CP	30% CP	35% CP	40% CP
Yellow Maize	57.65	48.19	38.72	29.26	19.78	10.32
Groundnut cake	10.21	19.21	28.24	37.24	46.27	55.28
Fish meal	4.08	7.69	11.29	14.90	18.51	22.11
Rice bran	19.21	16.06	12.90	9.75	6.59	3.44
Groundnut oil	5.00	5.00	5.00	5.00	5.00	5.00
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50	0.50	0.50	0.50
Vit-min premix (Poultry layer)	0.60	0.60	0.60	0.60	0.60	0.60
Salt (common salt)	0.25	0.25	0.25	0.25	0.25	0.25
Total:-	100	100	100	100	100	100

to meet the requirement for catfish (NRC, 1976).

The preparation of the diets was based on the description of Gardling and Wilson (1976). All ingredients were finely grounded and each ingredient was weighed according to formulation (Table 6). These were then mixed thoroughly with palm oil and some hot water until a paste was formed. Pellets were made through an improvised pelleting, device and were then dried to a constant weight in Galenkamp oven present at 65 ^{o}C. The pellets were allowed to cool and stored in labelled, dried bottles where they were dished out for the feeding trials.

3.4.3 Experimental units/experimental procedure

Concrete tanks, each measuring 1.20m x 0.85 x 0.45m were used for the experiments. Tap-water which had been stored for 48 hours to allow for dechlorination of the water was supplied into all the tanks. The experiment was conducted in four stages namely, feeding of:

(1) Fingerlings

(2) Juveniles

(3) Adult males

(4) Adult females.

The different stages were classified according to the recommendation of Viveen (1986):

Stage	Size range	Weight range
Fingerlings	3 - 10 cm	2 - 10 gms
Juveniles	10 - 30 cm	10 - 30 gms
Adults	32 - 140 cm	30 - 160 kgs

The initial weight for the fingerlings was 9.06 $\pm$ 1.21 gms; juveniles 21.20 $\pm$ 1.42 gms; adult males 98.87 $\pm$ 1.97 gms and adult females 100.25 $\pm$ 1.35 gms.

3.4.4 Feeding trials of the fingerlings, juveniles and adult males and females

The fingerlings were divided into five dietary groups viz:- Diet 1, 2, 3, 4 and 5 with 40%, 35%, 30%, 25%, and 20% crude protein diet respectively. The juvenile fish were also divided into five dietary groups viz - diet 2, 3, 4, 5 and 6 with dietary crude protein level of 35%, 30%, 20% and 15% respectively. The

adult male fish were fed on diets 3, 4, 5 and 6. Each dietary group contains 30%, 75%, 20% and 15% crude protein respectively. The adult females were in five dietary groups namely Diets 2, 3, 4, 5 and 6. Each group was treated with 35%, 30%, 25%, 20% and 15% dietary crude protein levels respectively.

Fingerlings were stocked at 6 fish per tank, juveniles at 4 fish per tank and the adult fish at 2 fish per tank. All fish were weighed before stocking. Each fish was marked at the dorsal spine by tagging with threads, so that individual fish was uniquely identified by a tank number. Prior to the feeding trials, all fish were starved for 48 hours to ensure that their guts were emptied. The fish were fed daily at 3% of their total body weight according to the recommendation of Bardach et al, (1972) and Viveen et al, (1986). The daily ration, was divided into two, one portion was fed at 9.00 a.m. and the other portion at 4.00 p.m. daily. Feeding in all tanks was generally completed in about 10-15 minutes. The fish ingested the food voraciously that only few particles

were observed after the feeding sessions.

Fish were reweighed every forthnight and the feeding rate adjusted accordingly to accomodate for any weight change. Each stage of the experiment lasted for 8 weeks.

3.4.5 Water quality management

Water in all tanks was changed fortnightly throughout the feeding trials. Temperature was measured with mercury thermometer. P^H was determined by a pH-meter while dissolved oxygen was measured by an oxygen meter. Water in all tanks was aerated.

3.5.0 Chemical evaluation of experimental diets and fish

Samples of experimental diets and experimental fish were analysed for their proximate composition, according to the methods of A.O.A.C. (1980).

3.5.1 Moisture content

The moisture contents of the different diets and fish samples were determined according to the method of A.O.A.C. (1980). 5g of each sample was weighed separately and placed in a known weight of

alluminium dish. This was placed in a Galenkamp oven pre-set at 105°C for 24 hours. The sample was dried to constant weight.

Calculation:

$$\text{Moisture content}(\%) = \frac{\text{weight of fish sample}(g) - \text{weight of dried sample}(g)}{\text{weight of fresh sample}(g)} \times 100$$

3.5.2 Crude protein

Determination of crude protein was done by Kjeldahl method (A.O.A.C., 1980). 1g of each of the samples was put in a labelled kjeldahl digestion flask. A digestion mixture comprising, 0.7g of mercuric oxide, 10g of potassium sulphate and 20 ml of sulphuric acid; was added into the digestion flask. The flask was gently heated at an inclined angle until the frothing from the flask subsided and the solution became clear. The flask was allowed to cool. On cooling, 90 ml of distilled water was added to the solution and was recooled, then 25 ml of sulphide solution was added and mixed together. A small piece of boiling chip to prevent bumping and 80 ml of sodium hydroxide solution were added while

tilting the flask so that two layers were formed. This was connected rapidly to the condenser unit, and heated. The distilled ammonia was collected in 50 ml boric acid/ indicator solution. 50 ml of distillate was collected. On completion of distillation, the receiver, (wash condenser tip) was removed and titrated against hydrochloric acid standard solution (0.1 N) and the volume of hydrochloric acid used was recorded.

The percentage nitrogen in the sample was calculated using the formula below:

$$\text{Nitrogen content of sample (\%)} = \frac{\text{Volume of acid(ml)} \times \text{normality of standard acid} \times 0.014 \times 100}{\text{weight of sample (g)}}$$

The percentage crude protein in each sample was calculated by multiplying the percentage nitrogen in the sample by a factor of 6.25. This method assumes that protein in the sample approximately consists of 16% nitrogen (Jobling, 1983).

3.5.3 Determination of crude fat or lipid

Residue from moisture content determination was transfered to an extraction thimble, making sure that any hard lumps formed during drying were carefully

broken into small pieces before the transfer. The thimble was placed in the extractor and was connected to flask (of known weight) containing 100 ml petroleum ether. The extractor was connected to a reflux condenser where sample was extracted under reflux in a water bath for 2 - 3 hours. The petroleum ether extract was evaporated to dryness and 2 ml of acetone added. Air was blown gently into the flask to remove the last traces of solvent. The flask containing the fat residue was dried in an air oven at 100°C for 5 minutes. It was cooled in a desiccator and weighed.

Calculation:

$$\text{Crude fat}(\%) = \frac{\text{Weight of residue(g)}}{\text{weight of sample}} \times 100$$

3.5.4 Determination of total ash

2g of the sample was weighed into a dry, tared procelain dish and was placed in muffle furnace set at 600°C for 6 hours. The dish from the furnace was cooled in a desiccator for at least one hour. The sample was weighed after cooling.

Calculation:

Let: weight of sample (g) = W_1

weight of ash (g) = W_2

% ash = $(W_2/W_1) \times 100$

3.5.5 Determination of crude fibre

The amount of the crude fibre content in the samples was determined using the acid/base digestion process (A.O.A.C. 1980).. 2g of the dried, fat-free sample was put into a 600 ml beaker, and 200 ml of 1.25% sulphuric acid was added. The beaker and its content were placed under condenser and the content boiled within 1 minute. The boiling continued for another 30 minutes, distilled water was used to wash down particles adhering to the sides of the beaker. The content of the flask was filtered through Whatman No. 541 paper in a Buchner funnel, using suction and was washed well with boiling water.

The residue was transfered back to the beaker and 200 ml of hot sodium hydroxide solution (1.25%) was added and replaced under condenser. After boiling for exactly 30 minutes, it was filtered through porous

crucible and washed in series, with boiling water, then with 1% hydrochloric acid and again with boiling water. The washing continued twice with alcohol, three times with acetone and dried at 100°C to constant weight. The sample was ashed at 500°C for 3 hours, cooled and weighed. The weight of fibre was calculated by difference.

Calculation:

$$\text{Crude fibre \%} = \frac{(\text{wt.of crucible+dried residue}) - (\text{wt.of crucible+residue})_{\text{ashed}}}{\text{weight of sample}}$$

3.5.6 Carbohydrate determination

The carbohydrate content was estimated 'by difference that is, by deducting the sum of the measured moisture, ash protein, fat and crude fibre from the total weight. This method does not take into account the inaccuracies associated with the determination of other constituents.

3.6 Determination of growth and nutrient utilization parameters

3.6.1 Weight gain (WTG)

The weight gained by fish was calculated from the difference between the final mean weight and the initial

mean weight, that is,

Final mean weight of fish - Initial mean weight.

3.6.2 Percentage weight gain (PWG)

The percentage weight gain was calculated from the formula:

$$\% \text{ weight gain} = \frac{100(Y - X)}{X}$$

where Y = Final mean body weight (g)

X = Initial mean body weight (g).

3.6.3 Specific growth rate (SGR)

SGR was calculated according to the method of Brown (1957) as:

$$SGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \times 100$$

where W_2 = weight of fish at time T_2 in days

W_1 = Weight of fish at time T_1 in days

Log_e = Natural log to base e.

3.6.4 Daily rate of growth (DRG)

This is calculated from the formula:

$$DRG = \frac{\text{Mean increase in weight per day}}{\text{Body weight of fish}}$$

3.6.5 Food conversion ratio (FCR)

The food conversion ratio (FCR) is expressed as the proportion of dry food fed per unit live weight gain of fish (Reay 1979).

$$FCR = \frac{\text{weight of dry feed fed(g)}}{\text{Live weight gain(g)}}$$

3.6.6 Gross food conversion efficiency (GFCE)

The gross food conversion efficiency was calculated according to Stickney (1979), as a percentage of the reciprocal of conversion ratio.

$$GFCE = \frac{1}{FCR} \times 100$$

3.6.7 Protein intake (PI)

The protein intake was calculated according to Garling and Wilson (1976) in the formula:

Protein intake(g) = feed intake(g) x % protein in the diet.

3.6.8 Protein efficiency ratio (PER)

PER was calculated using the method of Osborne and Mendel (1919) as:

$$PER = \frac{\text{Gain in weight of test fish(g)}}{\text{protein consumed(g)}}$$

The PER expresses the measure of the dietary protein utilization by the fish.

3.6.9 Nitrogen metabolism (Nm)

This was calculated using the method of Dabrowski (1977) as:

$$Nm = \frac{(0.54)(b-a)h}{2}$$

where a = initial weight of fish

b = final weight of fish

h = experimental period in days

0.54 = experimental constant.

3.6.10 Apparent net protein utilization (ANPU) or Productive protein value (PPV)

The ANPU or PPV is expressed as a percentage of protein retained in the fish body to the total protein ingested and does not take into consideration the endo genous protein losses (Jackson et al, 1982).

$$\text{ANPU OR PPV} = \frac{B - B_o}{PI} \times 100$$

where B = Final protein content of fish body

B_o = Initial protein content of fish body

PI = Protein Intake.

3.7.0 Statistical Analysis

Experimental results were subjected to the analysis of variance tests (Anova). Prediction equations, correlation coefficients, using IBM computer CSPSH (1976 version).

Chapter 4

4.0 Results

4.1 Reproduction in C. nigrodigitatus

4.1.1 Monthly changes in sex ratio

The monthly changes in the sex ratios of C. nigrodigitatus are shown in Table 7. It was observed that between the months of January and June the females predominated over males, while between months of July and December the males predominated. The pooled data for the twelve months however shows that out of the 304 specimens examined, 170 were females and 134 were males. This gives an overall sex ratio of 1 male to 1.27 females.

4.1.2 Size at maturity

In C. nigrodigitatus, the size at maturity for the females was 13.20 cm (standard length) while that for males was 16.50 cm (standard length). The smallest mature female had a standard length of 11.50 cm while the standard length for smallest mature male was 14.00cm.

Table 7: Sex-ratio of C. nigrodigitatus

Month	Total No. fish	No. of females	No. of males	% females	% males	Sex ratio female:male
Jan.	21	13	8	61.90	38.10	1.63:1
Feb.	24	14	10	58.33	41.69	1.40:1
Mar.	33	20	13	60.61	39.40	1.54:1
Apr.	43	32	11	74.42	25.58	2.91:1
May	32	26	6	81.25	18.75	4.33:1
June	25	16	9	64.00	36.00	1.78:1
July	22	10	12	45.45	54.55	0.83:1
Aug.	17	7	10	41.18	58.82	0.70:1
Sept.	18	7	11	38.89	61.11	0.64:1
Oct.	19	6	13	31.58	68.42	0,46:1
Nov.	24	10	14	41.67	58.33	0.71:1
Dec.	26	9	17	34.62	65.38	0.53:1
Total	304	170	134	55.92	44.08	1.27:1

4.1.3 Sexual dimorphism in C. nigrodigitatus

Secondary sexual characters were apparent in C. nigrodigitatus. In the mature male fish the colour of the body changed from bluish-grey to black and slightly bluish. The skin appeared dull and sticky due to the presence of mucous. The head and the mouth become broader and wider than the body (fig.4). The lower lip changed from pinkish colour to whitish pale colour. The "antenna" of the pectoral fins were no longer sharp but became rounded with a thick layer of mucous.

In the mature female fish, the head was narrower and pointed than the male fish (Fig.4). There was roundness of abdomen. The genital papilla became prominent and pinkish in colour. The edge of the pectoral fins were not sharp. Body colour became slightly dull.

4.1.4 Egg size and fecundity

The diameters of 15 randomly selected eggs from each specimen of ripe ovary ranged from 2.95 to 3.50 mm. The mean egg diameter was 3.20 $\pm$ 0.25 mm.

(a) (b)

Fig. 4 : Secondary sexual characters in Chrysichthys nigrodigitatus

(a) Female fish with a narrow head, pointed mouth and rounded body.

(b) Male fish with a broad head, wide mouth and slender body

Fecundity of 63 ripe females (stage IV of Nikosky 1963) was estimated. The number of fish eggs ranged from 254 for a 12.20 cm female to 1,138 for 15.50 cm female, with a mean fecundity of 560 $\pm$ 202. The lowest and highest fecundity were not observed in the smallest and biggest specimens. Fecundity for the smallest mature female was 470 while fecundity for the biggest mature female of 18.50 cm was 550.

The relationship between fecundity and body length is given by:

$\text{Log}_{10}F = 1.6841\text{Log}l + 0.7617$

the exponential equation for this relationship is

$F = 5.777L^{1.684}$; $r = 0.50$.

The relationship between fecundity and body weight is given by:

$\text{Log}_{10}F = 0.81.201\text{log}W + 1.1690$

$F = 14.76W^{0.8120}$

$r = 0.55$.

The relationship between fecundity and ovary weight is given by:

$\text{Log}F = 1.011\text{Log}Wg + 1.6363$

$F = 43.28Wg^{1.011}$

$r = 0.9726$.

where F = fecundity

L = body length cm

W = body weight g

Wg = ovary weightg

r = correlation factor.

4.1.5 Monthly variation in the gonadosomatic index(GSI), hepatosamatic index (HSI) and the condition factor(K) of C. nigrodigitatus.

The monthly GSI, HSI, and K of males and females of C. nigrodigatus are presented in Table 8. The mean monthly GSI for the females started to rise from 5.95 in September to 6.60 in December reaching a peak of 9.69 in February when the ovary was fully developed. There was a sudden fall in March and April to values of 6.00 and 6.50 respectively. In May, it had a value of 7.13 and by June, there was a sudden fall to a value of 3.15 which fluctuated till August. The GSI of the male fish were relatively high from the months of July to February (0.40 - 0.37) and low from March to June, (0.18 - 0.21).

The mean values of HSI in the females and males of C. nigrodigitatus fluctuated throughout the year, lowest in the months of March and April during the

-Table 8 - Monthly variation in Gonado-somatic index, Hepatosomatic index and condition factor of *Chrysichthys nigrodigitatus*.

Month	Length range (cm)	Weight range (gm)	Sex	GSI	HSI	K
JAN.	12.20-17.80	43.00-101.64	F	9.40±8.63	1.06±0.38	1.98±0.24
	16.50-18.50	82.25-147.50	M	0.37±0.23	0.98±0.21	2.14±0.33
FEB.	13.00-18.60	41.70-106.44	F	9.69±10.30	0.93±0.55	1.83±0.25
	15.50-18.00	74.10-118.00	M	0.37±0.25	0.99±0.17	2.18±0.26
MAR.	13.00-19.50	41.70-98.92	F	6.00±8.43	0.88±0.57	1.70±0.20
	15.80-19.50	79.30-128.00	M	0.18±0.14	0.80±0.32	1.95±0.39
APR.	13.00-18.00	43.64-140.58	F	6.50±8.63	0.74±0.35	1.84±0.26
	13.50-21.00	44.82-157.63	M	0.21±0.08	0.82±0.20	2.10±0.25
MAY.	13.20-18.50	45.86-107.07	F	7.13±8.10	1.02±0.40	1.88±0.30
	14.00-18.50	53.58-140.00	M	0.15±0.04	0.94±0.20	2.19±0.27
JUNE	12.50-17.50	50.61-96.19	F	3.15±5.00	0.99±0.38	2.06±0.30
	14.60-20.00	73.71-151.14	M	0.21±0.10	0.73±0.15	2.02±0.20
JULY	13.00-17.00	56.25-82.20	F	3.91±5.20	0.83±0.32	2.04±0.36
	13.30-18.90	64.99-179.39	M	0.40±0.11	1.03±0.30	2.43±0.20
AUG.	13.50-19.70	42.40-115.50	F	3.62±3.0	0.85±0.20	2.02±0.29
	15.60-17.60	86.82-144.60	M	0.42±0.13	1.01±0.26	2.45±0.20
SEPT.	13.00-17.50	50.20-96.19	F	5.896±7.76	1.14±0.59	2.10±0.30
	11.70-17.50	42.12-123.88	M	0.38±0.13	0.95±0.18	2.41±0.15
OCT.	13.00-15.50	43.23-79.80	F	5.30±4.92	1.30±0.28	1.95±0.22
	11.70-17.80	36.10-122.71	M	0.50±0.11	0.97±0.13	2.33±0.26
NOV.	11.00-18.50	25.63-147.50	F	6.23±6.60	1.34±0.53	1.95±0.40
	11.00-17.00	34.93-86.63	M	0.40±0.10	1.09±0.16	2.39±0.24
DEC.	11.50-18.00	41.26-115.00	F	6.60±7.37	1.01±0.29	2.05±0.34
	12.50-18.00	48.02-118.52	M	0.41±0.08	1.06±0.21	2.28±0.23

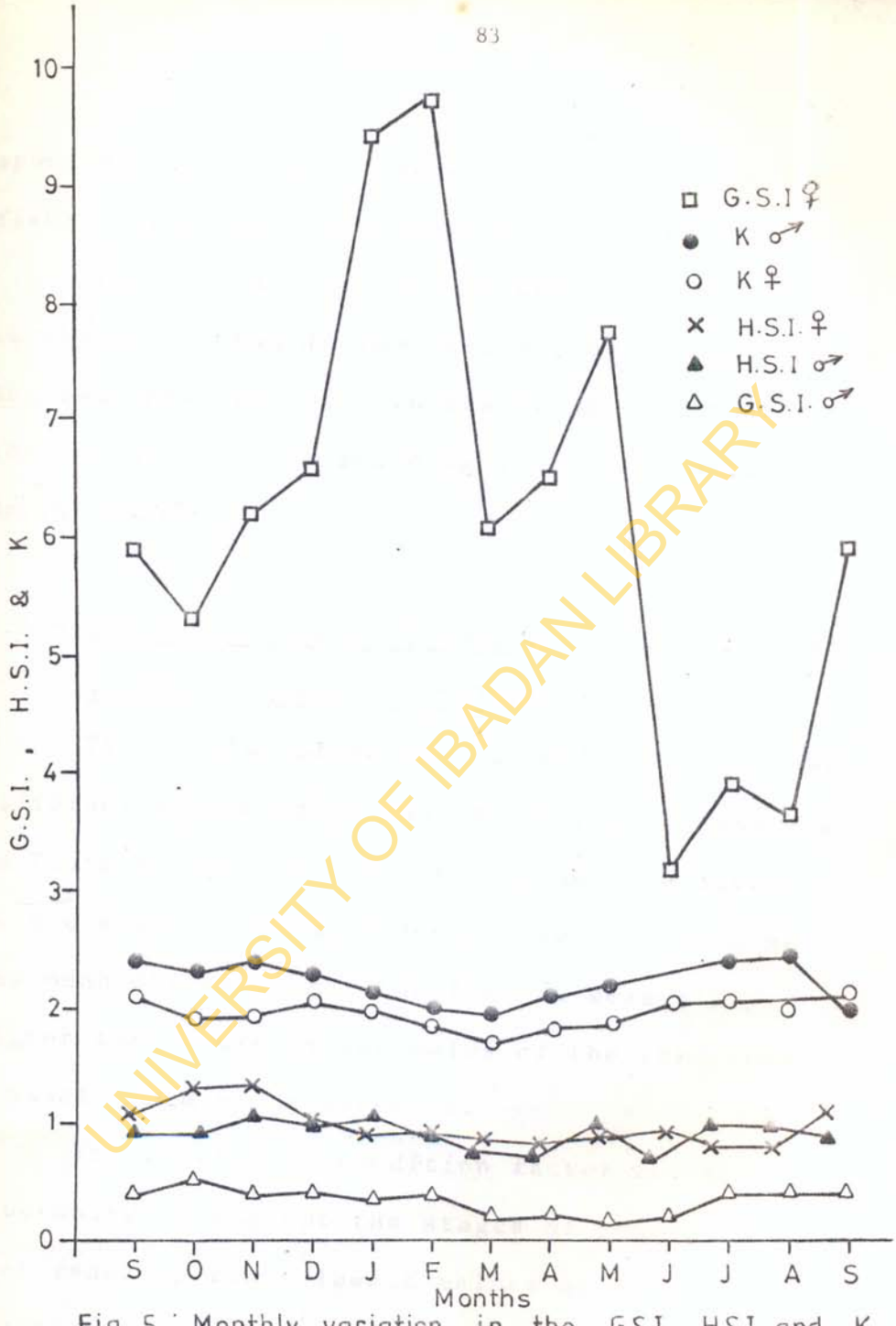

Fig. 5 : Monthly variation in the GSI, HSI and K of C. nigrodigitatus.

spawning season (when there were mature and spent fish). It gradually rose from June to November.

The results of K values were generally higher in the males than in the females, but showed almost the same pattern for both sexes. It fluctuated throughout the year reaching its lowest point in March. (fig.5)

4.1.6 Changes in the GSI, HSI, and K at different stages of gonadal development

The results of changes in GSI, HSI and K at different stages of gonadal development presented in Table 9 shows that GSI increased with increase in the stage of gonadal development for each sex. The mean GSI values for the females were always higher than those of the males of the corresponding gonadal stage of development.

The results of condition factor for both sexes fluctuated throughout the stages of gonadal development reaching their lowest values at stage V, during the spawning period. K was generally higher in the males than females at all stages of gonadal development except spawning (stage V).

Table 9 - Changes in GSI, HSI and K of C. nigrodigitatus at different stages of gonadal development

Parameter	Sex	Gonadal Stages I	II	III	IV	V	VI
GSI	F	0.13 ± 0.18^{af}	0.86 ± 0.37^{b}	4.54 ± 2.47^{c}	16.58 ± 4.37^{d}	12.66 ± 7.45^{e}	0.25 ± 0.19^{af}
	M	0.27 ± 0.10^{ad}	0.41 ± 0.10^{b}	0.42 ± 0.15^{b}	0.65 ± 0.12^{c}	0.65 ± 0.49^{c}	0.20 ± 0.08^{ad}
HSI	F	0.68 ± 0.43^{a}	0.93 ± 0.27^{a}	0.98 ± 0.21^{a}	1.28 ± 0.41^{b}	1.32 ± 0.31^{b}	0.56 ± 0.27^{c}
	M	0.95 ± 0.16^{a}	0.98 ± 0.26^{a}	0.97 ± 0.26^{a}	0.84 ± 0.24^{b}	0.46 ± 0.29^{b}	0.89 ± 0.16^{a}
K	F	1.95 ± 0.33^{a}	1.96 ± 0.17^{a}	2.07 ± 0.51^{a}	1.90 ± 0.25^{b}	1.79 ± 0.22^{c}	1.70 ± 0.19^{c}
	M	2.35 ± 0.24^{a}	2.39 ± 0.20^{a}	2.23 ± 0.30^{a}	2.29 ± 0.31^{a}	1.65 ± 0.02^{b}	2.11 ± 0.22^{ac}

Note - Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

The HSI in the female fish progressively increased with increase in gonadal stages up to stage V and fell sharply at stage VI after the fish had spawned. However, in the male fish the HSI values were almost the same in gonadal stages I, II and III and fell slightly to a value of 0.84 in gonadal stage IV, falling further down to its lowest value of 0.46 in stage V (spawning period) and increased again in stage VI after the fish had spawned.

HSI was higher in males than females in all stages of gondal growth except at the maturation of gonads (stage IV) and at spawning (stage V).

4.1.7 Changes in the crude protein, total lipid, total energy and ash contents of the muscle, liver, and ovaries of C. nigrodigitatus at different stages of gonadal development

The results of changes in the total lipid, crude protein, total ash and energy contents of the carcass, liver and ovaries are presented in Table 10. In the female fish there was a significant increase ($P < 0.05$) in the total body lipid during the initial stage of

Table 10 - Changes in the total lipid, crude protein, ash and energy contents of the carcase: liver and ovaries of C.nigrodigitatus

Parameter	Sex	Gonadal stages I	II	III	IV	V	VI
Muscle lipid	F	9.95 ± 1.02^{a}	12.60 ± 1.11^{b}	15.07 ± 0.97^{c}	7.37 ± 1.73^{d}	11.16 ± 1.00^{e}	11.54 ± 1.16^{e}
	M	10.01 ± 1.28^{a}	11.83 ± 1.39^{ab}	11.14 ± 1.10^{bc}	11.24 ± 1.20^{bc}	11.23 ± 1.10^{bcd}	12.59 ± 0.12^{d}
Muscle protein	F	55.54 ± 0.87^{a}	53.86 ± 1.44^{b}	55.53 ± 1.04^{ac}	55.45 ± 0.99^{ac}	55.43 ± 1.01^{ac}	54.67 ± 0.55^{ac}
	M	51.53 ± 2.22^{a}	53.61 ± 0.53^{a}	55.26 ± 1.02^{b}	53.98 ± 1.54^{ac}	54.25 ± 1.45^{c}	52.51 ± 0.40^{d}
Muscle ash	F	18.90 ± 4.37^{a}	17.00 ± 2.30^{a}	17.03 ± 1.24^{a}	19.78 ± 1.20^{b}	16.97 ± 0.72^{ac}	18.00 ± 0.80^{e}
	M	19.95 ± 1.75^{a}	18.11 ± 2.30^{a}	17.28 ± 1.10^{a}	20.99 ± 1.05^{b}	17.19 ± 0.60^{ac}	20.10 ± 0.60^{e}
Muscle energy	F	341.31 ± 15.56^{a}	357.64 ± 19.67^{b}	363.57 ± 2.31^{c}	313.15 ± 18.84^{d}	342.40 ± 4.57^{e}	335.25 ± 10.24^{e}
	M	324.45 ± 10.93	349.52 ± 14.74	342.02 ± 2.17	332.00 ± 6.34^{d}	340.35 ± 2.63^{e}	330.79 ± 6.64^{f}
Liver protein	F	54.35 ± 1.39^{a}	56.02 ± 0.71^{a}	55.60 ± 0.61^{a}	55.15 ± 1.00^{a}	54.85 ± 1.07^{a}	55.01 ± 1.12^{a}
	M	47.80 ± 1.40^{a}	46.93 ± 0.96^{a}	47.25 ± 1.11^{a}	46.73 ± 0.99^{a}	45.21 ± 1.20^{a}	44.97 ± 1.07^{a}
Liver lipid	F	12.49 ± 0.78^{a}	12.84 ± 1.21^{a}	13.10 ± 1.14^{a}	17.45 ± 2.41^{b}	17.79 ± 1.61^{b}	10.20 ± 1.21^{c}
	M	11.49 ± 0.30^{a}	16.45 ± 1.01^{b}	16.07 ± 1.12^{b}	9.27 ± 1.56^{c}	16.00 ± 1.31^{bd}	18.97 ± 2.08^{e}
Egg protein	F	-	-	63.79 ± 2.31^{a}	62.55 ± 3.25^{a}	65.65 ± 3.74^{a}	-
Egg lipid	F	-	-	2.5 ± 1.33^{a}	3.22 ± 1.40^{a}	2.16 ± 1.14^{a}	-
Egg ash	F	-	-	4.93 ± 1.71^{a}	11.78 ± 1.18^{b}	10.30 ± 1.04^{b}	-
Egg energy	F	-	-	309.36 ± 1.14^{a}	329.58 ± 4.47^{b}	323.08 ± 5.58^{b}	-

Note - Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

gonadal growth (stages 1 - III), followed by a significant sharp decrease ($P<0.05$) at the maturation of the ovaries (stage IV) and gradually increased at spawning and immediately after spawning (stages V and VI).

In the male fish there was little variation in the total body lipid at all stages of gonadal development. In both sexes, the level of body protein remained fairly constant. Female fish had greater total protein content than the males.

The ash content of the carcasses in both sexes showed insignificant variation ($P>0.05$) at the initial stage of gonadal growth (stages I, II and III). At maturation (stage IV) however, the ash content increased significantly ($P<0.05$) but suffered a significant loss ($P<0.05$) during spawning (stage V). It increased again after spawning (stage VI).

There was a significant increase ($P<0.05$) in the energy content of the carcass of the female fish at the initial stages of gonadal growth (stages I, II and III). This was followed by a significant reduction ($P<0.05$) at the maturation of the gonads (stage IV). In the males, the energy contents of the carcasses at the maturation

of gonads (stage IV) and at spawning (stage V) were significantly lower ($P < 0.05$) than those in other stages of gonadal development.

There were no significant differences ($P > 0.05$) in the protein and lipid contents of eggs in gonadal stages III, IV and V. However, the ash content of the eggs in gonadal stage III was significantly ($P > 0.05$) lower than those in stages IV and V. Generally, the protein contents of the eggs in stages III, IV and V were relatively higher than those of the body and liver.

4.2.0 Semi-artificial spawning in C. nigrodigitatus

The result of semi-artificial spawning in C. nigrodigitatus is presented in Table 11. There was no evidence of spawning for the couple in the bamboo confinement inside the concrete tank, however, spawning occurred between 36 and 48 hours after pairing in that placed inside the Asejire lake. The mean egg diameter of the fertilized egg (water hardening) was 4.70mm $\pm$ 0.02 while the weight was 4.50 $\pm$ 0.15mg. The fertilized eggs which had been transferred to

the laboratory hatched between 48 - 50 hours after spawning. Hatchability was estimated to be about 80% of the total eggs spawned. The length of the newly hatched larvae was 6.65mm ± 0.08; while the weight was 4.65mg ± 0.13. The mean diameter of the yolk sac of the newly hatched larvae was 4.5mm ± 0.14.

The mean temperature at the spawning site was 22.8°C ± 0.22; the dissolved oxygen was 7.20 ± 0.44mg/l while the pH was 6.94 ± 0.23. The incubation temperature was 23.1 ± 0.45°C; incubation oxygen was 6.90 ± 0.77mg/litre; while the pH was 6.95 ± 0.25.

Table 11: Features in semi-artificial spawning of C. nigrodigitatus

Parameter		Result
No. of pair of spawner	=	Two
No spawned	=	One
Initial weight of male	=	99.82g
Initial weight of female	=	98.97g
Final weight of female	=	80.63g
Loss in weight of female	=	18.34g
Estimated No. of egg spawned	=	807
% hatchability	=	80%
No. of eggs hatched	=	646
Spawning time	=	36 - 48 hrs.
Mean egg diameter of fertilized egg	=	4.70 ± 0.02 mm
Mean weight of fertilized egg	=	4.50 ± 0.02 mg
Total length of newly hatched	=	6.65 ± 0.08 mm
Mean weight of newly hatched	=	4.65 ± 0.13 mg
Diameter of yolk sac	=	4.50 ± 0.14 mm
Temperature at spawning site	=	22.8 ± 0.22°C
Dissolved oxygen at spawning site	=	7.20 ± 0.44 mg/1
pH at spawning site	=	6.94 ± 0.23
Incubation period	=	48 - 50 hrs.
Incubation temperature	=	23.1 ± 0.45°C
Incubation oxygen	=	6.90 ± 0.77 mg/1
Incubation pH	=	6.95 ± 0.25

4.2.1 Morphological and behavioural observation of larval development

Newly hatched (1st day).

The head of the newly hatched somehow curved over the yolk sac. The notochord was visible. There was the presence of finfold covering the entire length of the posterior part of the body. Eye pigmentation was observed, also there were pigmentations on the head. Larvae were observed to cluster in masses in the dark corners of the rearing tank, displaying a sporadic movement. The average weight was 4.65 ± 0.13 mg, while the total body length was 6.65 ± 0.03 mm. The yolk sac diameter was 4.50±0.02mm (Figure 6).

2nd day (Fig.7)

The segmentation of notochord was clearly visible. Optic vesicle was also visible. Lower jaw remain attached to the yolk. There was a slight decrease in t size of yolk sac, about 4.30 ± 0.02 mm in diameter. The length of the larva had increased to 7.50±0.01 mm weighing 5.20±0.25 mg. Larval activity tended to increas

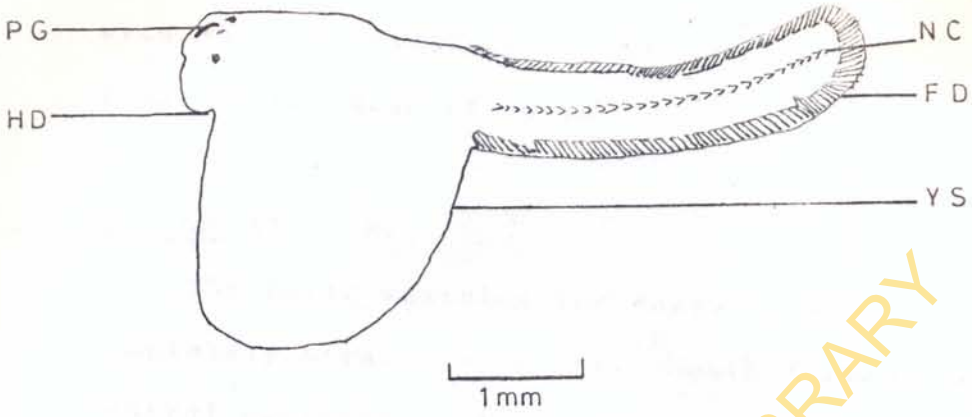

Fig. 6 : Newly hatched larva of Chrysichthys nigrodigitatus

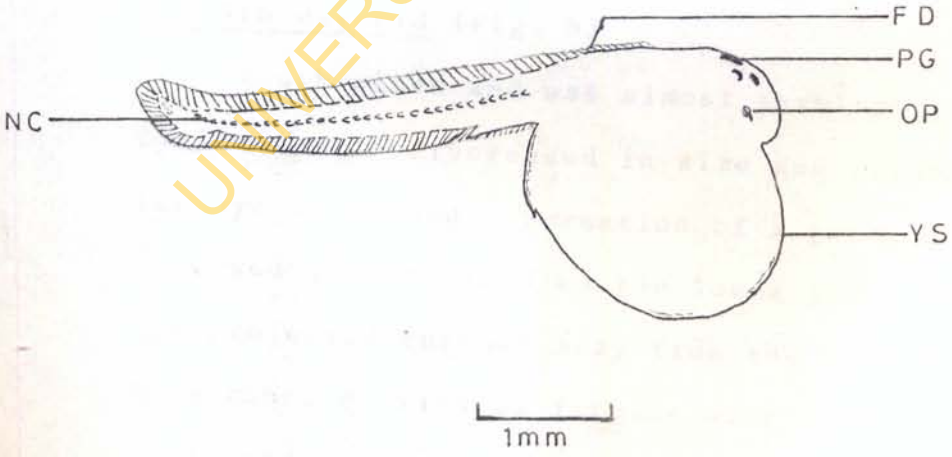

Fig. 7 : 2-day old larva of Chrysichthys nigrodigitatus

with muscular flextures of the tail. Pigments were found on the head of larva.

3rd day (Fig. 8)

The optic vesicles increased in size. Head completely straightened out. Mouth forming in the ventral position. Lower jaw had slightly projected beyond the yolk. The snout pointed downward and finfold was still present. Blood cells were visible in circulation. The yolk sac diameter range of 4.50 ± 0.22 mm at hatching had decreased to an average of 3.80 ± 0.15 mm. The larva had increased in size with a mean length of 9.00 ± 0.25 mm, and a weight of 8.5 ± 0.17 mg.

4 - 5th day old (Fig. 9)

Mouth widen and was almost terminal in position. Optic vesicles increased in size and pigmentation of the eye increased. Formation of a pair of barbel was observed as skin fold on the lower jaw. The lower jaw projected further away from the yolk sac. Appearance of fins as finbuds within the finfold. Lower and upper jaws were vibrating very well. Larva

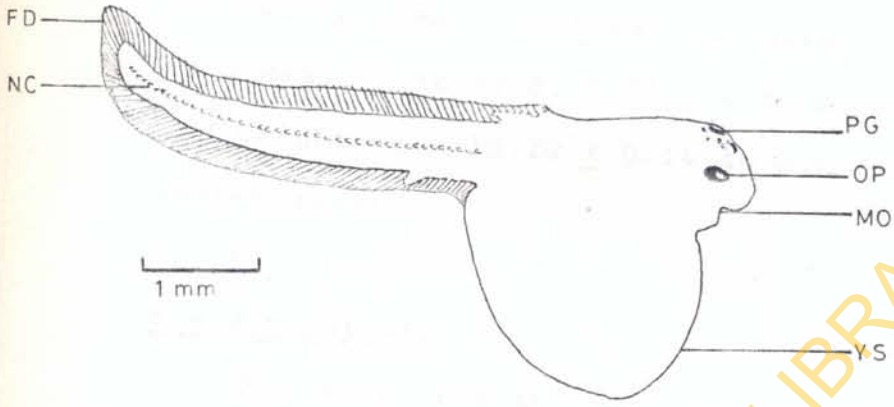

Fig. 8 : 3 - day old larva of Chrysichthys nigrodigitatus

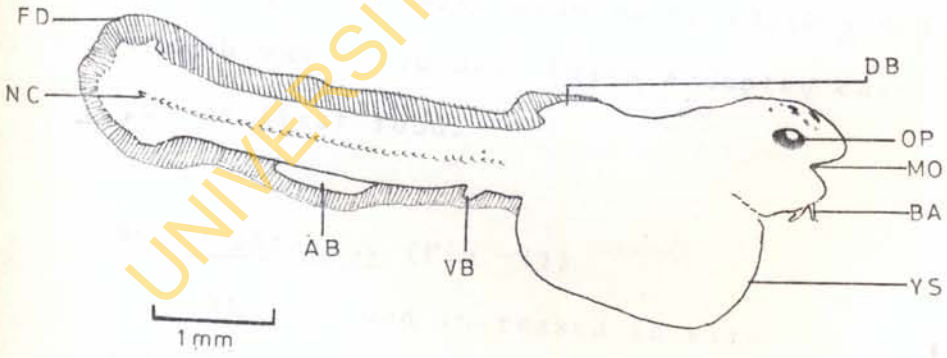

Fig. 9 : 4 to 5 day old larva of Chrysichthys nigrodigitatus

was capable of moving vertically but the yolk prevented it from floating. Yolk sac continued to decrease in size to a mean diameter of 1.75 ± 0.23 mm while larval length and weight were 13.20 ± 0.14 mm and 15.70 ± 0.21 mg respectively.

6 - 8th day old (Fig. 10)

Eye increased in diameter and was deeply pigmented. Fins were developed and their rays were visible. The caudal fin was in homocercal condition (truncated). There was a flange of finfold connecting dorsal and caudal fins to the anal fin. There was an increase in the spread of melanophores. The last vestige of the yolk sac was still present, about 0.50 ± 0.01 mm. The weight of the larva reduced to 13.10 ± 0.10 mg and the length was 13.50 mm. Larva accepted cultured zooplankton as first food.

9th - 10th day (Fig. 11)

The eye had increased in size. Mouth was completely formed. The ventral fins had differentiated out. Fins were well formed and very distinct. Dorsal fin had assumed a fan-like shape. Caudal fins was turcated. The

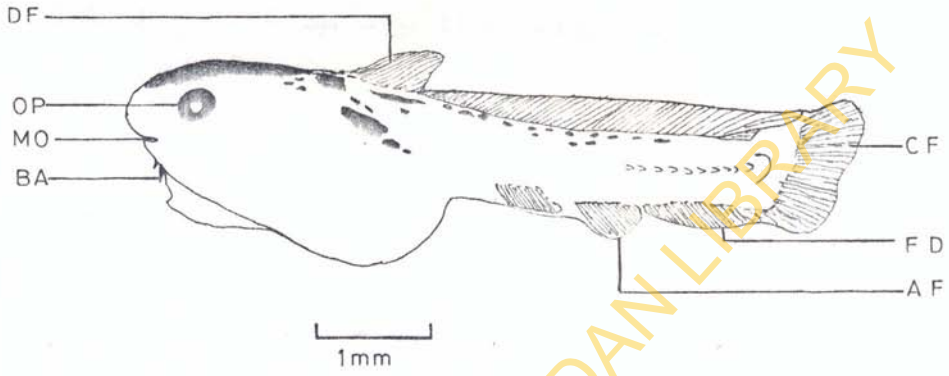

Fig. 10 : 6 - 8 day old larva of Chrysichthys nigrodigitatus

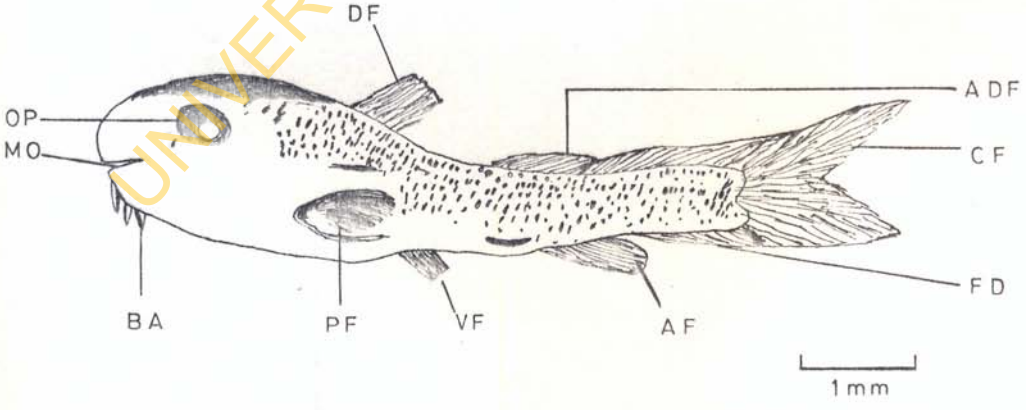

Fig. 11 : 9 - 10 day old larva of Chrysichthys nigrodigitatus

dorsal fin rays had ossified. Melanophores had sprea to all parts of the body. Larva assumed a fish-like shape and actively swimming. The yolk sac was fully absorbed. The mean length of the larva was 16.50 ± 0.30 mm and the weight was 13.50 ± 0.24 mg.

Fig. 6 - 11 : Stages in the larval development of *C. nigrodigitatus*

List of abbreviations used:

AB = Anal fin bud

ADF = Adipose dorsal fin

AF = Anal fin

BA = Barbel

CF = Caudal fin

DB = Dorsal fin bud

DF = Dorsal fin

EYP = Eye pigmentation

FD = Finfold

HD = Head

MO = Mouth

NC = Notochord

OP = Optic lobe

PF = Pectoral fin

PG = Pigmentation

VB = Ventral fin bud

VF = Ventral fin

YS = Yolk sac

4.2.2 Exogenous feeding trials in C. nigrodigitatus larvae

The result of the exogenous feeding trials of C. nigrodigitatus larvae is presented in Table 12. Both the total body length and body weight of larvae fed on plankton were higher than the group fed on 40% dietary protein level. All larvae fed on 35% and 30% crude protein levels died at the end of 5 days of exogenous feeding.

The specific growth rate (SGR) and condition factor (K) of larvae fed on live plankton were 13.24 and 1.024 respectively. In the group fed on 40% crude protein level, the specific growth rate was 1.46 and the condition factor (K) was 0.345. The terminal survival rates of 26% and 2% were observed in larvae fed on live plankton and 40% crude protein respectively.

4.2.3 Mean total length of larvae and yolk sac diameter

The relationship between total length and yolk sac diameter in C. nigrodigitatus larvae is shown in figure 12. There was a general decrease in the yolk sac diameter as the larva increased in length. There was a rapid yolk absorption when the total length was between 9.00 and 13.20 mm. The yolk was completely utilized

Table 12 - Growth responses of Chrysichthys nigrodigitatus larvae on natural and artificial diets.

Parameter	Diet A (100% Plankton)	Diet B 40% CP	Diet C 35% CP	Diet D 30% CP
No of larvae	50	50	50	50
Initial mean length (mm)	17.00±0.21	17.00±0.20	17.00±0.10	17.00±0.15
Initial mean weigth (mg)	15.50±0.17	15.50±0.11	15.48±0.50	15.51±0.12
Length at day 7 (mm)	19.20±0.02	17.40±0.02	-	-
Weigth at day 7 (mg)	60.91±0.37	18.50±0.01	-	-
Final mean length at 14 day (mm)	21.30±0.05	17.65±0.00	-	-
Final mean weigth at day 14 (mg)	98.97±0.41	19.00±0.00	-	-
Daily increase in weight (mg)	5.96±0.74	0.223±0.29	-	-
Daily increase in length (mm)	0.31±0.02	0.05±0.00	-	-
Specific growth rate (SGR)	13.24±8.91	1.46±1.57	-	-
Condition factor (k)	1.024	0.345	-	-
% mortality	74	98	100	100
No of survivors	13	1	0	0
% Survivors	26	2	0	0

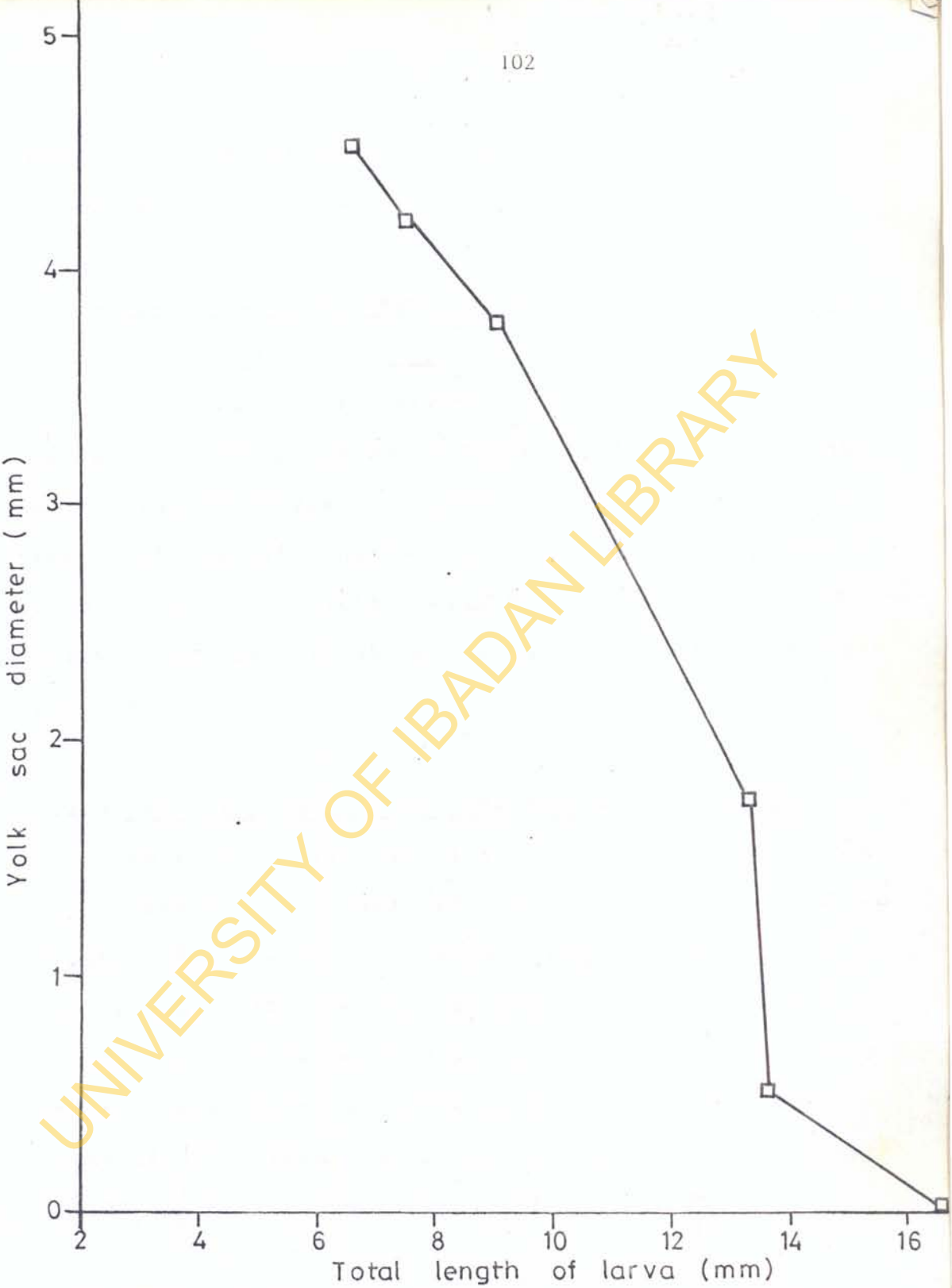

Fig. 12 : Relationship between the total length of larvae and yolk sac diameter of C. nigrodigitatus

when the larvae attained an average total length of 16.50 mm.

4.2.4 Changes in the weight of larvae during the period of endogenous feeding

The relationship between the average weight of larvae and time is shown in figure 13. The mean weight of the larvae increased steadily from the first day to the fifth day after hatching. There was a sharp drop from the sixth day to the eighth day, and increased slightly at day 10th which marked the end of the endogenous feeding.

4.2.5 Mortality rate during the endogenous feeding

Mortality during the initial ten days after hatching is presented in Table 13. High mortalities occurred twice during the first 10 days. The first high motality took place on the 3rd and 4th days and accounted for 9.46% and 9.15% respectively. A second major mortality of 14.26 and 13.49% occurred on the 7th and 8th day respectively. These two critical periods accounted for 46.40% of the total mortality rate of 62.22%.

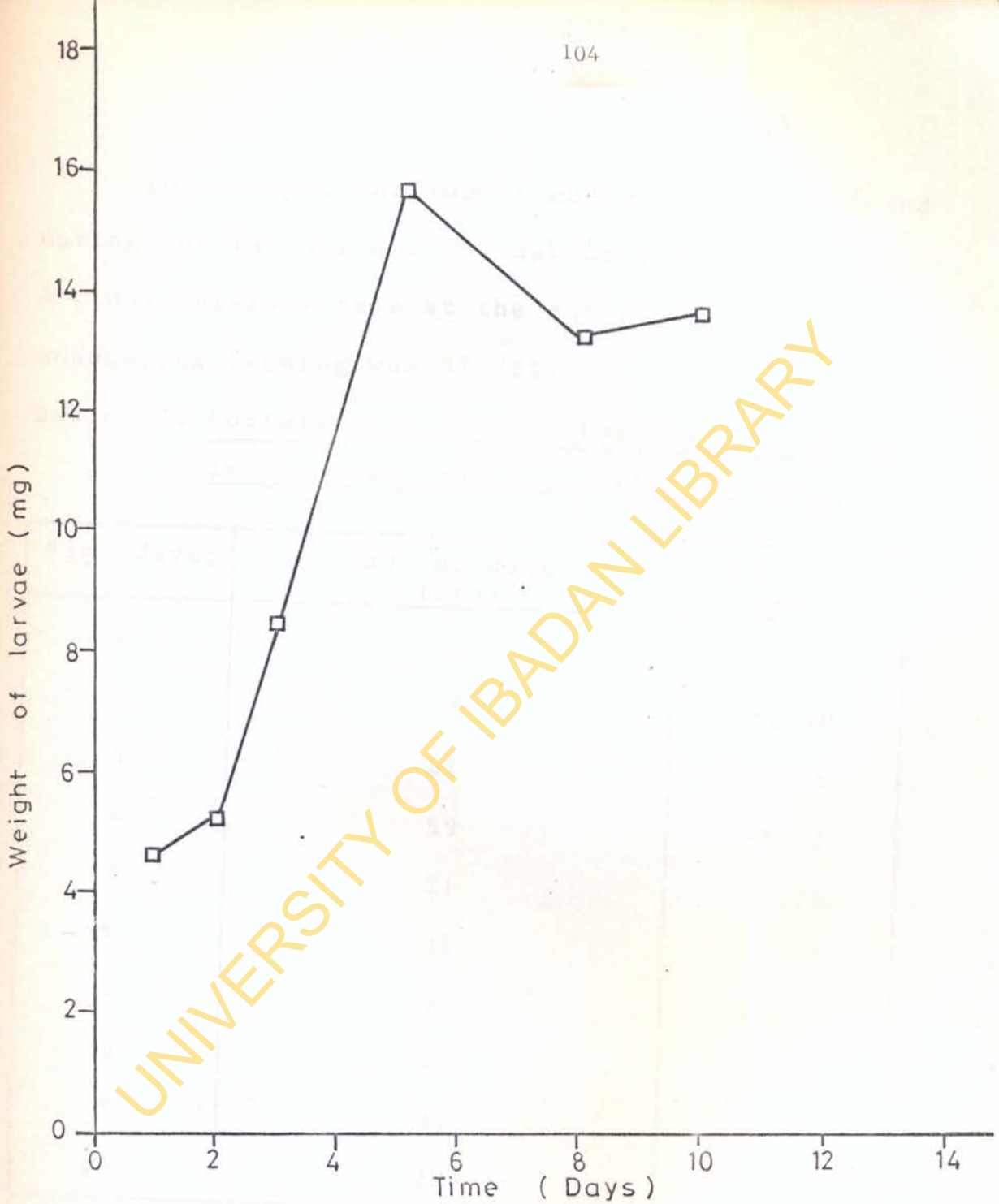

Fig. 13 : Relationship between weight of larvae (mg) and time (days) in C. nigrodigitatus

In general, the lowest mortalities were found during the 1st day and 2nd day of larval development. A final survival rate at the end of the 10 days of endogenous feeding was 37.78%.

Table 13: Mortality of Chrysichthys nigrodigitatus in the first ten days after hatching

Time(days)	No. of dead larvae	Percentage mortality
1	7	1.08
2	9	1.40
3	61	9.46
4	59	9.15
5	21	3.26
6	31	4.81
7	92	14.26
8	87	13.49
9	22	3.41
10	12	1.87

4.3.0 Growth responses and nutrient utilization parameters of the fingerlings of C. nigrodigitatus fed on experimental diets.

4.3.1 Weight changes (WTC) and weight gain (WTG)

The results of weight changes and the subsequent gain in weight, are presented in Table 14. The average initial weight of fish of 9.50 ± 0.59 gm increased with time. At the end of the feeding trial, the best average weight gain of 3.60 ± 1.21 gm was achieved with diet 2 containing 35% crude protein (CP) and the least value of 0.72 ± 0.20 gm with diet 5 containing 20% CP. The results of statistical analysis showed that there was no significant ($P>0.05$) difference in the mean weight gain value in diets 1 (35%CP) and 2 (40%CP). However, there were significant ($P<0.05$) differences between them and diets 3, 4 and 5.

The predictive equations relating weight gain with dietary protein levels is:

$$Y = -0.7943 + 2.0041X \quad \text{(Table 20).}$$

where Y = Weight gain

X = Dietary protein level.

The calculated r (correlation coefficient) value is 0.9776, showing that the relationship is linear.

Table 14 - Weight changes and weight gain of C. nigrodigitatus fingerlings fed on experiental diets.

Growth Parameters	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	S.G
WTC	Week 0	9.50±0.59^{a}	9.37±0.65^{a}	9.32±0.52^{a}	9.00±0.53^{a}	9.06±0.63^{a}	0.0966	n.s
	" 2	12.28±0.52^{a}	11.88±0.67^{a}	10.54±0.67^{b}	9.85±0.63^{c}	9.53±0.59^{c}	0.1976	.
	" 4	15.02±0.44^{a}	14.76±0.51^{a}	12.43±0.55^{b}	11.06±0.60^{c}	10.19±0.51^{d}	0.3190	.
	" 6	18.80±0.35^{a}	18.47±0.48^{a}	15.27±0.53^{b}	12.52±0.47^{c}	10.91±0.39^{d}	0.5146	.
	" 8	23.86±0.51^{a}	23.73±0.65^{a}	18.41±0.71^{b}	15.02±0.71^{c}	11.67±0.56^{d}	0.4272	.
WTC	" 2	2.70±0.46^{a}	2.51±0.51^{a}	1.15±0.33^{b}	0.85±0.31^{bc}	0.60±0.18^{c}	0.1501	.
	" 4	2.74±0.30^{a}	2.95±0.60^{a}	1.89±0.68^{b}	1.28±0.45^{c}	0.66±0.11^{d}	0.1552	.
	" 6	3.83±0.42^{a}	3.71±0.36^{a}	2.84±0.25^{b}	1.47±0.26^{c}	0.61±0.13^{d}	0.2073	.
	" 8	5.01±0.55^{a}	5.26±0.35^{a}	3.14±0.43^{c}	1.01±0.43^{c}	1.01±0.42^{d}	0.2620	.
	Mean value	3.57±1.09^{a}	3.60±1.21^{a}	2.26±0.91^{b}	1.53±0.70^{c}	0.72±0.20^{d}	0.1018	.

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05).

* Significant (P<0.05). n.s. = Not significant. S.E. = Standard error.

The correlation matrix (Table 21) shows that WTG was significantly (P 0.05) and positively correlated with all measured parameters except for the food conversion ratio which was negatively correlated.

4.3.2 Percentage weight gain (PWG)

The result of PWG is shown in Table 15. This follows the same pattern as that of WTG. Diet 2 had the highest PWG, followed closely by diet 1 and then diets 3, 4 and 5 in that order. There was no significant difference ($P > 0.05$) between the results of PWG in diets 2 and 1, but there were significant differences ($P < 0.05$) between them and diets 3, 4 and 5.

The result of regression equation relating PWG (V) to different dietary protein level (X) (Table 20) showed that PWG was linearly related to dietary treatments. The equation is $Y = 1.41107 + 12.6614X$, $r = 0.9653$.

Table 15 - Percentages weight gain (PWG) and specific growth rate (SGR) of C. nigrodigitatus fingerlings fed on experimental diets

Growth Parameters	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	SIG
PWG	Week 2	28.36±5.97^{a}	27.00±6.40^{a}	12.25±3.54^{b}	9.48±3.43^{b}	6.72±2.10^{c}	1.6095	.
	" 4	22.41±2.98^{a}	25.05±6.01^{a}	17.95±7.07^{b}	13.21±5.29^{b}	6.93±1.51^{c}	1.2816	.
	" 6	25.59±3.36^{a}	25.22±2.92^{a}	22.94±2.38^{b}	13.26±2.67^{c}	6.02±1.29^{d}	1.2975	.
	" 8	26.63±3.16^{a}	28.47±1.91^{a}	20.54±1.41^{b}	19.93±3.40^{b}	9.33±3.60^{c}	1.1568	.
	Mean	25.75±2.50^{a}	26.44±1.62^{a}	18.42±4.59^{b}	13.97±4.35^{c}	7.25±1.44^{d}	1.7800	.
SGR	Week 2	1.95±0.45^{a}	1.70±0.35^{a}	0.78±0.21^{b}	0.65±0.22^{b}	0.46±0.14^{c}	0.1056	.
	" 4	1.44±0.18^{a}	1.66±0.25^{a}	1.18±0.43^{b}	0.88±0.33^{b}	0.39±0.17^{c}	0.0841	.
	" 6	1.63±0.19^{a}	1.61±0.17^{a}	1.48±0.14^{b}	0.84±0.12^{c}	0.45±0.07^{d}	0.07892	.
	" 8	1.68±0.18^{a}	1.79±0.11^{a}	1.33±0.06^{b}	1.30±0.20^{b}	0.55±0.19^{c}	0.07362	.
	Mean value	1.68±0.21^{a}	1.69±0.08^{a}	1.19±0.30^{b}	0.92±0.27^{c}	0.46±0.07^{d}	0.1439	.

Figures in the same horizontal row having similar superscript are not significantly different ($P>0.05$).

* Significant ($P< 0.05$), n.s. = Not significant S.E. = Standard error.

4.3.3 The specific growth rate (SGR)

The mean specific growth rate of the fingerlings during the experimental period ranged from 0.46 to1.69 (Table 15). The best SGR was obtained in diet 2, and the least value in diet 5. The values of 1.69 obtained in diet 2 and that of 1.68 in diet 1 were not significantly different. The relationship between SGR (Y) and dietary protein levels (X) is $Y = -0.09274 + 0.08199X$ ($r = 0.9677$). The correlation matrix in Table 21 shows that SGR was positively and significantly correlated with other measured parameters

4.3.4 Daily rate of growth (DRG)

The daily rate of growth (Table 16) was significantly influenced by dietary treatments. Diet 2 had the highest daily growth rate and diet 5 had the lowest rate. Statistically, there was no significant difference between ($P > 0.05$) DRG values in diet 1 and that of diet 2. The equation describing DRG (Y) with different dietary protein level (X) is:

$Y = 0.00811 + 0.00887X$ (Table 20).

r value = 0.9578.

Table 16 - Daily rate of growth (DRG) of C. nigrodigitatus fingerlings fed on experimental diets.

Growth Parameter	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	S.G
DRG	Week 2	0.020 ± 0.0041^{a}	0.019 ± 0.0045^{a}	0.0088 ± 0.0026^{b}	0.0068 ± 0.0026^{b}	0.0048 ± 0.0015^{c}	0.00115	.
	" 4	0.016 ± 0.0021^{a}	0.018 ± 0.0043^{a}	0.013 ± 0.0051^{b}	0.0098 ± 0.0041^{c}	0.0049 ± 0.0011^{d}	0.00092	.
	" 6	0.018 ± 0.0028^{a}	0.018 ± 0.0022^{a}	0.016 ± 0.0019^{b}	0.0096 ± 0.0020^{c}	0.0043 ± 0.0097^{d}	0.00093	.
	" 8	0.019 ± 0.0022^{a}	0.021 ± 0.0012^{a}	0.015 ± 0.0011^{b}	0.014 ± 0.0025^{c}	0.0067 ± 0.0026^{d}	0.00084	.
	Mean value	0.018 ± 0.0017^{a}	0.019 ± 0.0014^{a}	0.013 ± 0.0032^{b}	0.010 ± 0.0032^{b}	$0.005175\pm$? ^{d}	0.00043	.

Figures in the same horizontal row having similar superscript are significantly different from one another ($P > 0.05$).

S.E = Standard error
= Significant ($P < 0.05$)
n.s = not significant.

As with other growth parameters, DRG was positively and significantly ($P < 0.05$) correlated with other measured parameters (Table 21) except for FCR which was negatively but significantly correlated ($P < 0.05$).

4.4.4 Food conversion ratio (FCR)

The result of FCR for the fingerlings of *C. nigrodigitatus* is presented in Table 17. The mean FCR value ranged from 1.64 to 6.48. Diet 2 had the best FCR value of 1.64 and diet 5 had the poorest value of 6.48. Statistical analysis showed that there was no significant difference ($P > 0.05$) between the mean value obtained in diet 1 and that of diet 2, but there were significant differences between them and the values obtained in diets 3, 4 and 5.

The correlation matrix in Table 21 shows that FCR was negatively but significantly ($P < 0.05$) correlated with dietary protein levels and all measured parameters. The regression equation in Table 20 relating FCR(Y) with different dietary protein levels (X) is: $Y = 7.5804 - 2.8249X$, with $r = -0.8822$.

Table 17 - Food conversion ratio (FCR) and Gross food conversion efficiency (GFCE) of C. nigrodigitatus fingerlings fed on experimental diets

Growth Parameters	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	S.G
FCR	Week 2	1.53 ± 0.28^{a}	1.63 ± 0.36^{a}	3.75 ± 1.33^{b}	5.00 ± 2.00^{c}	6.95 ± 2.34^{c}	0.3994	.
	" 4	1.91 ± 0.30^{a}	1.77 ± 0.46^{a}	2.67 ± 1.10^{b}	3.60 ± 1.27^{c}	6.23 ± 1.34^{d}	0.3009	.
	" 6	1.67 ± 0.24^{a}	1.69 ± 0.21^{a}	1.85 ± 0.22^{b}	3.27 ± 0.69^{c}	7.35 ± 1.81^{d}	0.3726	.
	" 8	1.60 ± 0.19^{a}	1.48 ± 0.10^{a}	2.05 ± 0.14^{b}	2.16 ± 0.36^{c}	5.22 ± 2.35^{d}	0.2732	.
	Mean value	1.68 ± 0.16^{a}	1.64 ± 0.12^{a}	2.58 ± 0.85^{bc}	3.04 ± 1.07^{c}	6.43 ± 0.93^{d}	0.1442	.
GFCE	Week 2	67.53 ± 14.17^{a}	64.37 ± 15.30^{a}	29.14 ± 8.43^{b}	22.52 ± 8.16^{b}	15.92 ± 5.10^{bc}	3.8420	.
	" 4	53.39 ± 7.09^{a}	58.80 ± 15.27^{a}	51.65 ± 15.04^{a}	31.43 ± 12.5^{b}	16.69 ± 3.64^{c}	3.0061	.
	" 6	60.89 ± 8.01^{a}	60.07 ± 6.82^{a}	54.63 ± 5.67^{a}	31.87 ± 6.98^{b}	14.27 ± 3.13^{c}	3.0910	.
	" 8	63.41 ± 7.53^{a}	67.72 ± 4.56^{a}	48.92 ± 3.34^{b}	47.40 ± 8.05^{b}	22.30 ± 8.7^{c}	2.7453	.
	Mean value	61.31 ± 5.94^{a}	62.74 ± 4.09^{a}	46.09 ± 11.53^{b}	33.31 ± 10.34^{c}	17.30 ± 3.49^{d}	4.2453	.

Figures in the same horizontal row having similar superscript are not significantly different at ($P > 0.05$)

* Significant at ($P < 0.05$) n.s. = Not significant: S.E. Standard error.

4.4.5 Gross food conversion efficiency (GFCE)

The result of GFCE is presented in Table 17. The highest GFCE value of 61.31 was obtained in diet 2 while the lowest value of 17.30 was obtained in diet 5. The values of GFCE obtained in diets 1 and 2 were not significantly ($P > 0.05$) different.

The regression equation relating GFCE with experimental diets is $Y = -2.6497 + 29.961X$ and r value = 0.9615 (Table 20).

The correlation matrix (Table 21) shows that GFCE was significantly and negatively correlated with FCR at $P < 0.05$ but positively and significantly correlated ($P < 0.05$) with other measured parameters.

4.4.6 Protein efficiency ratio (PER)

The result of PER in Table 18 shows that the best PER value was obtained in diet 2 while the least value was in diet 5. Statistical analysis within the mean values showed that the values of PER in diets 1 and 2 were not significantly different ($P > 0.05$) from one another but were significantly different to other diets.

The correlation matrix (Table 21) showed that PER was positively and significantly correlated ($P < 0.05$) with all measured parameters except for the FCR which was negatively correlated ($P < 0.05$).

4.4.7 Nitrogen metabolism (Nm)

The mean nitrogen metabolism (Table 18) ranged from 14.50 for the fish that received diet 2 to 2.78 for the fish that received diet 5. Statistically, there was no significant ($P > 0.05$) difference between the mean Nm values obtained in diets 1 and 2; however, they were significantly ($P < 0.05$) different from values obtained for other diets. The equation relating Nm (Y) with dietary protein levels (X) as shown in Table 20 is: $Y = -3.2866 + 7.883X$. The correlation coefficient (r) is 0.9757.

The result of correlation matrix (Table 21) showed that Nm was positively and significantly correlated ($P < 0.05$) with all other measured parameters except for the FCR which showed a negative but significant ($P < 0.05$) correlation.

Table 18 - Protein efficiency ratio (PER) and Nitrogen metabolism (Nm) of C. nigrodigitatus fingerlings on experimental diests

Growth Parameters	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	S.G
P.E.R.	Week 2	1.69 ± 0.35^{a}	1.84 ± 0.43^{a}	0.95 ± 0.27^{c}	0.90 ± 0.33^{c}	0.80 ± 0.25^{c}	0.08433	.
	" 4	1.33 ± 0.17^{a}	1.61 ± 0.30^{a}	1.44 ± 0.56^{a}	1.26 ± 0.50^{a}	0.83 ± 0.18^{c}	0.07079	.
	" 6	1.52 ± 0.20^{a}	1.71 ± 0.20^{a}	1.82 ± 0.19^{a}	1.26 ± 0.25^{b}	0.72 ± 0.15^{c}	0.06976	.
	" 8	1.59 ± 0.19^{a}	1.94 ± 0.15^{a}	1.63 ± 0.11^{ab}	1.89 ± 0.33^{ab}	1.09 ± 0.42^{b}	0.06178	.
	Mean value	1.53 ± 0.15^{a}	1.78 ± 0.15^{a}	1.46 ± 0.37^{ab}	1.33 ± 0.41^{ab}	0.86 ± 0.16^{b}	0.05354	.
Nm	Week 2	10.36 ± 1.75^{a}	9.64 ± 1.94^{a}	4.41 ± 1.29^{b}	3.27 ± 1.19^{c}	2.31 ± 0.67^{d}	0.5796	.
	" 4	10.53 ± 1.15^{a}	12.69 ± 4.44^{a}	7.25 ± 2.60^{b}	4.93 ± 1.74^{c}	2.54 ± 0.42^{d}	0.6962	.
	" 6	15.07 ± 2.08^{a}	14.25 ± 1.40^{a}	10.93 ± 0.95^{c}	5.64 ± 0.98^{c}	2.36 ± 0.48^{d}	0.8129	.
	" 8	19.25 ± 2.15^{a}	20.20 ± 1.35^{a}	12.06 ± 1.00^{b}	9.59 ± 1.64^{c}	3.89 ± 1.60^{d}	0.006	.
	Mean value	13.80 ± 4.24^{a}	14.20 ± 4.44^{a}	8.66 ± 3.50^{b}	5.86 ± 2.68^{c}	2.78 ± 0.75^{d}	0.3932	.

Figures in the same horizontal row having the same superscript are not significantly different ($P>0.05$).

* Significant ($P<0.05$)
S.E. = Standard error.

4.4.8 Cummulative growth response and nutrient utilization parameters of C. nigrodigitatus fingerlings

The result of commulative growth response and nutrient utilization of fish over the eight weeks of experimental period is presented in Table 19. In all the parameters tested diet 2 consistently showed superiority in values, to other diets. Statistically, however, all the results in diet 2 were not significantly different ($P > 0.05$) from those of diet 1, but were significantly different from the results of the other diets.

4.4.9 Productive protein value (PPV) or Apparent net protein utilization

The apparent net protein utilization values of 3.95, 3.62, 1.66, 1.34 and 0.89 were observed in fish fed diets 1, 2, 3, 4 and 5 respectively (Table 19). The ANPU decreased from 3.95 in fish fed on the highest amount of crude protein (40%) to 0.89 in fish fed on the lowest amount of crude protein (20%).

Table 19 - Cumulative growth response and nutrient utilization parameters of C. nigrodigitatus fingerlings fed on experimental diets

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	S.G
WTG	14.03 ± 0.76^{a}	14.29 ± 0.82^{a}	9.02 ± 0.70^{b}	6.02 ± 0.47^{c}	2.54 ± 0.50^{d}	0.7375	.
SGR	1.61 ± 0.11^{a}	1.66 ± 0.12^{a}	1.21 ± 0.09^{b}	0.92 ± 0.07^{c}	0.46 ± 0.09^{d}	0.0737	.
PWG	147.22 ± 16.00^{a}	153.96 ± 14.87^{a}	96.44 ± 11.19^{b}	67.12 ± 6.99^{c}	28.30 ± 6.85^{d}	7.8366	.
FCR	1.66 ± 0.13^{a}	1.61 ± 0.12^{a}	2.23 ± 0.21^{c}	2.97 ± 0.21^{c}	6.83 ± 1.52^{d}	0.3287	.
GFCE	60.08 ± 4.44^{a}	62.49 ± 4.34^{a}	45.12 ± 3.73^{b}	33.84 ± 2.50^{c}	15.31 ± 3.52^{d}	2.8532	.
PER	1.50 ± 0.11^{a}	1.79 ± 0.12^{a}	1.51 ± 0.12^{b}	1.35 ± 0.10^{c}	0.76 ± 0.18^{d}	0.05761	.
Nm	215.61 ± 11.65^{a}	219.72 ± 12.52^{a}	138.58 ± 10.74^{b}	92.54 ± 7.27^{c}	39.22 ± 7.53^{d}	11.3071	.
Apparent NPU or PPV	3.95 ± 0.00^{a}	3.62 ± 0.00^{a}	1.66 ± 0.00^{b}	1.34 ± 0.00^{c}	0.89 ± 0.00^{d}	0.00	

Figures in the same horizontal row having the same superscript are not significant different ($P > 0.05$).

* Significant ($P < 0.05$).

S.E. = Standard error.

Table 20 - Prediction equations relating growth and nutrient utilization parameters to dietary protein levels

Dependent variable	Independent variable	Prediction equation	r	r^2	S.E	S.G
WTG	Dietary protein level	Y = -0.7943+2.0041X	0.9776	0.9557	0.5663	.
PWG	"	Y = -1.41107+12.6614X	0.9653	0.9318	3.6235	.
DRG	"	Y = -0.000811+0.00887X	0.9578	0.9174	0.0026	.
SGR	"	Y = -0.09274+0.08199X	0.9677	0.9364	0.2341	.
FCR	"	Y = -7.58042-2.8249X	-0.8822	0.7783	0.8846	.
GFCE	"	Y = -2.6497+29.961X	0.9615	0.9245	8.6087	.
Nm	"	Y = -3.2866+7.8838X	0.9752	0.9510	2.2335	.
PER	"	Y = 0.6875+0.4510X	0.8207	0.6736	0.1518	.

* Significant ($P < 0.01$).

Table 21 - correlation matrix on growth responses and nutrient utilization parameters of C. nigrodigitatus fingerlings

Parameters	WTG	FCF	DRG	SGR	PWG	GFCE	FCR	PI	Nm	PER
WTG	1.0000**									
FCF	0.89537**	1.0000**								
DRG	0.90206**	0.62704**	1.0000**							
SGR	0.87197**	0.57698*	0.99493**	1.0000**						
PWG	0.89344**	0.61177**	0.99905**	0.99639**	1.0000					
GFCE	0.88213**	0.59803*	0.99407**	0.99136**	0.99438**	1.0000				
FCR	-0.82132**	0.56443*	-0.94271**	-0.93384**	-0.94147**	-0.94440**	1.0000			
PI	0.96315**	0.90747**	0.82036**	0.78880**	0.81190**	0.80060**	-0.74501**	1.0000		
Nm	0.99809**	0.88693**	0.90627**	0.87769**	0.89781**	0.88567**	-0.82115**	0.96074**	1.0000	
PER	0.80930**	0.57587*	0.90964**	0.90064**	0.90928**	0.90910**	-0.90910**	0.64879**	0.80741**	1.0000

** Significant (P 0.01)

* Significant (P 0.05)

Figures without * or ** are not significantly correlated (P 0.05)

4.4.10 Influence of experimental diets on the chemical body composition of the fingerlings

The chemical composition of the carcasses before and after the feeding trials showed that there were insignificant increase in fish carcasses' protein concentration with increasing dietary protein level (Table 22). However, the fish carcass lipid increased significantly ($P < 0.05$) with the increasing dietary protein level, except for diets 1 and 2 which were not significantly different ($P > 0.05$).

The ash content, the crude fibre and the carbohydrate content of the fish body did not show any particular trend of relationship with different dietary protein level. It was however, observed that water content of the fish body was inversely related to the body lipid content.

4.4.11 Results of physico-chemical properties of water in the experimental tanks (fingerlings).

Table 23 shows the mean water quality parameters recorded for each dietary crude protein level. The dissolved oxygen content of the water ranged from 6.85 - 8.21mg/l. Temperature was between 24.5 - 26.5°C

Table 23: Mean values of water quality parameters in fingerlings experimental tanks.

Parameter	Range	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Level of SIG.
Temperature(^{o}C)	24.5-26.5	25.5±1.00[a]	25.8±0.3[a]	25.5±1.00[a]	26.00±0.80	26.2± 0.50	n.s
Dissolved oxygen	6.85-8.21	7.52±0.50	6.85±0.80	7.98±0.16	8.12±0.09	8.00±0.16	n.s
pH	6.90-7,4	7.20±0.09	7.20±0.08	7.19±0.08	7.25±0.40	7.24±0.12	n.s

note: SIG = Significant
n.s = not significant

Table 22 - Proximate analysis of the body composition of the experimental fish (fingerlings)

Parameters %	Initial body composition	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.G
Crude protein	68.25±0.75^{a}	68.62±0.89^{a}	68.54±0.31^{a}	68.35±0.29^{a}	68.31±0.70^{a}	68.28±0.31^{a}	.
% Fat content	8.34±0.32^{a}	12.49±0.28^{b}	12.20±32^{b}	10.52±0.41^{c}	8.98±0.39^{d}	8.42±0.40^{a}	.
% Ash content	11.98±0.09^{a}	8.54±0.19^{b}	7.89±0.20^{c}	9.63±0.08^{d}	10.99±0.09^{e}	12.10±0.03^{f}	.
Moisture	10.51±0.06^{a}	9.49±0.08^{b}	9.80±0.05^{c}	9.97±0.07^{d}	9.96±0.06^{e}	10.00±0.02^{f}	.
Crude fibre	0.64±0.010^{a}	0.49±0.002^{b}	0.69±0.01^{c}	0.59±0.03^{d}	0.88±0.04^{e}	0.74±0.03^{f}	.
Carbohydrate	0.24±0.002^{a}	0.39±0.01^{b}	0.88±0.008^{c}	0.69±0.01^{d}	0.88±0.02^{e}	0.46±0.007^{f}	.
Total	100.00	100.00	100.00	100.00	100.00	100.00	

Figures in the same horizontal row having similar superscript are not significant ($P>0.05$) from one another.

n.s. = not significant

* significant at $P<0.05$

while the pH values ranged from 6.90 - 7.4. In all the dietary groups there were no significant differences ($P > 0.05$) in all the monitored water parameters.

4.5 Growth response and nutrient utilization parameters of juveniles of C. nigrodigitatus

4.5.1 Weight changes (WTC) and weight gain (WTG)

The results of WTC and WTG are shown in Table 24. Juveniles fed on diet 2 (35%CP) had the best weight gain while those fed on diet 6 had the least weight gain. Statistically, WTG values increased significantly ($P < 0.05$) with increasing levels of dietary protein.

The equation relating WTG (Y) with different dietary protein levels (X) is $Y = 1.0552 + 1.40X$ (Table 29). The calculated r value is 0.9958. The results of correlation matrix (Table 30) showed that all measured parameters viz: PWG, SGR, DRG, GFCE, PER, PI and Nm were all positively and significantly ($P < 0.05$) correlated with WTG. However, FCR was negatively but significantly ($P < 0.05$) correlated with WTG.

Table 24 - weight changes (WTC) and weight gain (WTG) of C. nigrodigitatus juveniles fed on experimental diets

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
WTC	Week 0	21.26±0.56^{a}	21.38±0.70^{a}	21.3±0.43^{a}	21.36±0.54^{a}	21.36±0.59^{a}	0.0858	.
	" 2	24.96±0.74^{a}	24.12±0.44^{b}	23.31±0.45^{c}	22.62±0.52^{d}	21.92±0.38^{e}	0.1889	.
	" 4	29.33±0.69^{a}	27.39±0.59^{b}	25.32±0.48^{c}	23.87±0.53^{d}	22.65±0.55^{e}	0.3938	.
	" 6	34.30±0.96^{a}	31.29±0.56^{b}	28.30±0.52^{c}	25.25±0.69^{d}	23.45±0.55^{e}	0.6318	.
	" 8	40.03±1.02^{a}	35.67±0.81^{b}	32.54±0.39^{c}	28.21±0.53^{d}	24.49±0.93^{e}	0.8816	.
Weight Gain	" 2	3.34±0.39^{a}	2.68±0.34^{a}	2.00±0.21^{c}	1.24±0.49^{d}	0.70±0.19^{e}	0.1593	.
(WTG)	" 4	4.34±0.72^{a}	2.91±0.38^{b}	1.96±0.20^{c}	1.26±0.38^{d}	0.72±0.31^{e}	0.2154	.
	" 6	4.99±0.66^{a}	3.92±0.30^{a}	2.88±0.63^{b}	1.38±0.34^{cd}	0.77±0.44^{d}	0.2610	.
	" 8	5.74±0.81^{a}	4.38±0.70^{a}	4.30±0.38^{b}	2.96±0.80^{bc}	1.04±0.53^{d}	0.2728	.
	Mean value	4.60±0.51^{a}	3.47±0.35^{b}	2.79±0.55^{b}	1.71±0.42^{c}	0.81±0.07^{d}	0.1000	.

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05)

* Significant (P< 0.05) n.s. = Not significant. S.E. = Standard error.

4.5.2 Percentage weight gain (PWG)

In the juvenile fish, the highest PWG was recorded for diet 2 (35%CP) while diet 6 (15%CP) had the lowest value (Table 25). In general, PWG increase with increasing level of dietary crude protein content throughout the experimental period. Statistically, there was no significant ($P > 0.05$) difference between the mean values of PWG in diets 3 and 4.

The equation relating PWG with dietary protein levels as shown in Table 29 is $Y = -2.3951 + 4.8054X$. The correlation coefficient (r) is 0.9899.

4.5.3 Daily rate of growth (DRG)

The daily rate of growth (DRG) among the different dietary groups increased with increasing level of dietary protein (Table 25). Diet 2 had the highest mean value of 0.012 and diet 6 the lowest mean value of 0.0027. Statistically, mean values of DRG in diets 3 and 4 were not significantly different at $P > 0.05$.

The equation describing daily growth rate with dietary protein levels (X) is $Y = 0.0016 + 0.0034X$

Table 25 - Percentage weight gain (PWG) and Daily rate of growth (DRG) of C. nigrodigitatus juveniles fed on experimental diet

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
% weight Gain (PWG)	Week 2	15.46±1.77^{a}	12.54±1.90^{b}	9.40±1.05^{c}	5.83±2.39^{d}	3.32±0.97^{e}	0.7498	n.s
	" 4	17.43±3.20^{a}	11.99±1.50^{b}	8.41±0.82^{c}	5.57±1.73^{d}	3.26±1.37^{e}	0.8481	.
	" 6	17.03±2.27^{a}	14.32±1.21^{b}	11.39±2.57^{c}	5.79±1.39^{d}	3.42±1.99^{e}	0.8691	.
	" 8	26.55±2.58^{a}	14.00±2.28^{b}	15.20±1.53^{bc}	11.80±3.36^{c}	4.43±2.22^{d}	0.7844	.
	Mean	19.12±2.51^{a}	13.21±0.56^{b}	11.10±1.50^{b}	7.25±1.52^{c}	3.61±0.28^{d}	0.3487	.
Daily rate of growth (DRG)	Week 2	0.011±0.0014^{a}	0.009±0.0014^{b}	0.0067±.00071^{c}	0.0042±.00071^{d}	0.0024±.00070^{e}	0.00053	.
	" 4	0.013±0.0025	0.0086±.0011	0.0060±.00059	0.0040±.0012	0.0023±.00099	0.00062	.
	" 6	0.011±0.0034^{a}	0.010±.00081^{b}	0.0082±.00020^{c}	0.0041±.00020^{d}	0.0028±0.0011^{e}	0.00060	.
	" 8	0.012±0.0019^{a}	0.0097±.00016^{b}	0.011±0.0011^{b}	0.0085±0.0025^{c}	0.0031±0.0016^{d}	0.00058	.
	Mean	0.012±.00096^{a}	0.0093±.00064^{b}	0.0080±.0022^{b}	0.0052±0.0022^{c}	0.0027±0.0037^{d}	0.0361	.

Figures in the same horizontal row having similar superscript are not significantly different ($P>0.05$)

* Significant ($P<0.05$) n.s. = Not significant S.E. = Standard error.

with r value of 0.9795.

Correlation matrix (Table 30) showed that DRG was significantly and negatively correlated with FCR (r = 0.8691) but positively and significantly correlated ($P < 0.05$) with other measured parameters.

4.5.4 Specific growth rate (SGR)

The result of the specific growth rate of the juvenile of C. nigrodigitatus is presented in Table 26. The SGR recorded during the feeding trials ranged from the lowest value of 0.25 in diet 6 to the highest value of 1.10 in diet 2. Like other growth parameters SGR of the trial fish increased proportionally with increasing dietary protein levels. Statistically, the value of SGR in diet 2 was significantly different from the values recorded for diets 3, 4, 5 and 6.

The predictive equation (Table 29) relating SGR to different dietary protein levels is $Y = -0.1298 + 0.3125X$. The correlation coefficient is 0.9858. The results of the matrix (Table 30) showed that SGR was significantly ($P < 0.05$) and positively correlated with other parameters except for FCR which showed a negative but significant ($P < 0.05$) correlation.

Table 26 - Specific growth rate (SGR) of C. nigrodigitatus juveniles fed on experimental diets

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
S.G.R.	Week 2	1.03 ± 0.15^{a}	0.87 ± 0.14^{b}	0.65 ± 0.06^{c}	0.40 ± 0.156^{d}	0.20 ± 0.10^{e}	0.0480	*
	" 4	1.15 ± 0.192^{a}	0.82 ± 0.19^{b}	0.59 ± 0.029^{c}	0.39 ± 0.12^{d}	0.23 ± 0.09^{a}	0.0554	*
	" 6	1.12 ± 0.14^{a}	0.95 ± 0.08^{b}	0.80 ± 0.14^{c}	0.40 ± 0.096^{d}	0.25 ± 0.156^{e}	0.0544	*
	" 8	1.11 ± 0.157^{a}	0.93 ± 0.144^{b}	1.00 ± 0.112^{b}	0.79 ± 0.216^{c}	0.31 ± 0.153^{d}	0.05073	*

Figures in the same horizontal row having similar superscript are not significantly different ($P>0.05$)

* Significant ($P\leq 0.05$).

S.E. Standard error.

4.5.5 Gross food conversion efficiency (GFCE)

The result of GFCE is in Table 27. The mean GFCE value ranged from 9.46 in diet 6 to 39.71 in diet 2. It increased proportionally with the increasing protein level. All values recorded for different dietary protein levels were significantly different at $P < 0.05$.

The correlation matrix (Table 30) showed that FCR was significantly and negatively correlated to GFCE. All other measured parameters were positively correlated ($P < 0.05$). The prediction equation of $Y = -5.1680 + 11.1619X$ (Y = GFCE; X = protein level at r value of 0.9965 in Table 25 shows that there was a linear relationship between the values of GFCE and the dietary protein levels.

4.5.6 Food conversion ratio (FCR)

The result of FCR in Table 27 shows an inverse relationship with dietary protein levels. The best FCR of mean value 2.57 was achieved in diet 2, while the poorest mean value of 13.47 was achieved in diet 6. There were no significant differences ($P > 0.05$) between the FCR values of diets 2 and 3 but these values were significantly different ($P < 0.05$) from

Table 27 - Gross food conversion efficiency (GFCE) and food conversion ratio of juveniles of C. nigrodigitatus fed on experimental diets

Parameters	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
GFCE	Week 2	36.84±4.23^{a}	29.91±4.58^{b}	22.38±2.49^{c}	13.90±5.69^{d}	7.90±2.30^{e}	1.7660	n.s
	" 4	41.50±7.61^{a}	28.62±3.49^{b}	20.11±2.08^{c}	13.28±4.13^{d}	8.88±4.01^{d}	1.9858	*
	" 6	40.57±5.41^{a}	34.05±2.95^{b}	27.11±6.11^{c}	13.80±3.30^{d}	10.51±4.45^{e}	1.9556	*
	" 8	39.94±6.11^{a}	31.40±8.15^{b}	30.19±3.68^{c}	28.11±7.97^{d}	10.55±5.28^{e}	1.8954	*
	Mean value	39.71±2.02^{a}	31.00±2.33^{b}	24.95±4.55^{c}	17.27±7.23^{d}	9.46±1.30^{e}	0.7689	*
(FCR)	Week 2	2.75±0.33^{a}	3.42±0.59^{b}	4.52±0.58^{c}	7.86±1.93^{d}	13.65±4.07^{e}	0.6887	*
	" 4	2.49±0.49	3.53±0.38	5.04±0.55	8.02±1.86	14.39±3.39	0.7241	*
	" 6	2.50±0.34^{a}	2.96±0.26^{b}	3.85±0.88^{b}	7.56±1.62^{d}	13.65±6.65^{d}	0.8880	*
	" 8	2.55±0.35^{a}	3.44±1.20^{ab}	2.79±0.27^{b}	3.88±1.38^{c}	12.20±6.65^{d}	0.7756	*
	Mean	2.57±0.12^{a}	3.34±0.26^{ab}	4.05±0.97^{b}	6.83±1.98^{c}	13.47±0.92^{d}	0.1902	

Figures in the same horizontal row having similar superscript are not significantly different . : (P>0.05).
S.E. = Standard error.
* = Significant at P<0.05.

the FCR values obtained in diets 5 and 6.

The matrix in Table 26 shows that FCR was negatively and significantly correlated with all growth and nutrient utilization parameters. The equation relating FCR (Y) with protein levels (X) is: $Y = 15.8409 - 3.6848X$. The correlation coefficient (r) is -0.8691 (Table 25).

4.5.7 Protein efficiency ratio (PER)

The protein efficiency ratio (PER) among the different dietary groups increased with increasing level of dietary crude protein (Table 28). Diet 2 had the best PER value of 1.15 and diet 6 had the lowest value of 0.55. Statistically, there were no significant differences ($P > 0.05$) between the mean PER values of fish fed on diets 2, 3, and 4, however, there were significant differences in the PER values of fish fed on diets 4, 5 and 6.

The correlation matrix in Table 30 shows that PER was positively and significantly ($P < 0.05$) correlated with all measured parameters except for the FCR which showed a negative correlation ($P < 0.05$).

4.5.8 Nitrogen metabolism Nm

The Nm values in Table 28 for juveniles fish were highest in diet 2 and lowest in diet 6. Nm values increased significantly ($P < 0.05$) with increasing levels of dietary protein. The correlation matrix (Table 30) showed that Nm value was was positively correlated ($P < 0.05$) with all measured parameters except for FCR which was negatively correlated to Nm. The prediction equation in Table 25 relating Nm with different levels of dietary protein is $Y = -4.0930 + 5.4477X$. The correlation coefficient (r) is 0.9962.

4.5.9 Productive protein value (PPV) or Apparent net nitrogen utilization (ANPU) of juveniles of C. nigrodigitatus

Productive protein value or apparent net nitrogen utilization is presented in Table 31. PPV values ranged from 0.64 in fish fed diet 5 to 3.09 in fish fed diet 2. Generally, PPV values increased with increasing level of dietary protein. Diet 6 with 15% dietary crude protein level had a zero PPV.

Table 28 - Protein efficiency ratio (PER) and nitrogen metabolism (Nm) of C. nigrodigitatus juveniles fed on experimental diets.

Parameters	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E.	S.G
Protein efficiency ratio (PER)	Week 2	1.05±0.12^{a}	1.00±0.15^{ab}	0.89±0.19^{ab}	0.71±0.27^{b}	0.46±0.23^{c}	0.0445	n.s
	" 4	1.19±0.22^{a}	0.95±0.12^{a}	0.80±0.07^{b}	0.66±0.21^{c}	0.52±0.22^{d}	0.0467	*
	" 6	1.21±0.20^{a}	1.14±0.10^{ab}	1.08±0.25^{ab}	0.69±0.16^{b}	0.54±0.31^{c}	0.0535	*
	" 8	1.14±0.18^{a}	1.11±0.18^{a}	1.45±0.15^{ab}	1.41±0.41^{b}	0.70±0.35^{c}	0.0593	*
	Mean	1.15±0.071^{a}	1.05±0.09^{ab}	1.05±0.29^{ab}	0.86±0.36^{b}	0.56±0.10^{c}	0.0371	*
Nitrogen metablolism (Nm)	Week 2	12.85±1.49^{a}	10.40±1.24^{b}	7.72±0.81^{c}	4.78±1.87^{d}	2.69±0.73^{e}	0.6065	*
	" 4	16.76±2.73^{a}	12.54±1.73^{b}	7.73±0.40^{c}	4.83±1.44^{d}	2.75±1.16^{e}	0.8567	*
	" 6	19.10±2.51^{a}	15.01±1.19^{b}	11.53±2.05^{c}	5.29±1.33^{d}	3.09±1.93^{e}	0.9924	*
	" 8	22.05±3.11^{a}	16.82±2.67^{b}	16.23±1.85^{c}	11.39±3.05^{d}	3.99±2.06^{e}	1.0487	*
	Mean	17.69±3.89^{a}	13.69±2.81^{b}	10.80±4.04^{c}	6.57±3.22^{d}	3.13±0.60^{e}	0.3753	*

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05).

* Significant (P<0.05) n.s. = Not significant. S.E. = Standard error.

Table 29 - Simple predictive equations, coefficients of determination and correlation coefficients relating each of the measure parameters to dietary protein levels for C. nigrodigitatus juvenile.

Dependent variable	Independent variable	Prediction equation	r	r^2	S.E	SIG
WTG	Dietary protein level	Y = -1.0552+1.4048X	0.9958	0.99163	0.6618	*
PWG	"	Y = -2.3951+4.8054X	0.9899	0.9800	2.2775	*
SGR	"	Y = -0.1298+0.3125X	0.9858	0.9719	0.1487	*
DRG	"	Y = -0.00160+0.0034X	0.9867	0.9795	0.0016	*
FCR	"	Y = 15.8409-3.6848X	-0.8691	0.7553	1.9891	*
GFCE	"	Y = -5.1680+11.1619X	0.9965	0.9930	5.2548	*
Nm	"	Y = -4.0930+5.4477X	0.9962	0.9923	2.5656	*
PER	"	Y = 0.4093+0.1991X	0.8907	0.7933	0.1049	*

* Significant at ($P < 0.01$)

S.E. = Standard error.

Table 30 - Correlation matrix, growth responses and nutrient utilization parameters for C. nigrodigitatus juvenile on experimental diets

Parameters	WTG	FCF	DRG	SGR	PWG	GFCE	FCR	PI	Nm	PER
WTG	1.0000									
FCF	0.83156**	1.00000								
DRG	0.94954**	0.62934*	1.0000							
SGR	0.95366**	0.63759*	0.9955**	1.0000						
PWG	0.96053**	0.65064*	0.99606**	0.99872**	1.0000					
GFCE	0.94764**	0.62673*	0.98768**	0.99241**	0.99224**	1.0000				
FCR	-0.83766**	-0.51577*	-0.90947**	-0.92376**	-0.91204**	-0.89899**	1.0000			
PI	0.96307**	0.81758**	0.89449**	0.91204**	0.91129**	0.91648**	-0.80148**	1.0000		
Nm	0.99849**	0.82497**	0.95222**	0.91129**	0.96250**	0.95163**	-0.84554	0.96582**	1.0000	
PER	0.85896**	0.61985**	0.89367**	0.89435	0.89319	0.85901**	-0.86295**	0.71050**	0.85638**	1.0000

* Significant ($P < 0.05$)

** Significant ($P < 0.01$)

Table 31 - Cummulative Growth Response and Nutrient Utilization Parameters of C. nigrodigitatus Juvenile on experimental diets

Parameters	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
WTG	18.42±0.61^{a}	14.22±0.85^{b}	11.23±0.39^{c}	6.84±0.47^{d}	3.17±0.75^{e}	0.1910	*
PWG	95.17±2.54^{a}	66.41±5.17^{b}	52.76±2.57^{c}	32.04±2.57^{d}	14.88±3.55^{e}	1.140	*
SGR	1.10±0.025^{a}	0.91±0.06^{b}	0.76±0.051^{c}	0.50±0.036^{d}	0.25±0.053^{e}	0.271	*
GFCE	198.56±1.75^{a}	154.98±2.02^{b}	124.74±3.94^{c}	86.36±6.26^{d}	47.30±1.12^{e}	2.096	*
PER	1.10±0.08^{a}	1.08±0.07^{b}	1.09±0.05^{c}	0.87±0.06^{d}	0.57±0.14^{e}	0.035	*
Nm	283.02±9.40^{a}	218.63±13.04^{b}	172.63±5.99^{c}	105.16±7.20^{d}	48.73±11.48^{e}	2.9172	*
Apparent NPU or PPV	3.09	2.96	1.84	0.64	0.00		

* Significant at $P<0.05$.

± S.E = Standard error.

Figures in the same horizontal row having similar superscript are not significantly different at $P>0.05$

4.5.10 Body composition of the juveniles of *C. nigrodigitatus* fed on experimental diets.

Table 32 shows the results of the body composition of *C. nigrodigitatus* juveniles before and after the feeding experiment. The body protein content of the experimental fish increased from 68.45 (initial body crude protein) to the highest value of 68.95 in diet 2 (35%CP). The body protein of fish fed on diet 6 (15%CP) did not change at the end of the feeding trials.

The lipid content of the juveniles fish increased significantly ($P < 0.05$) with increasing level of dietary protein. Diet 2 had the highest lipid deposition of 12.48% while diet 6 had the least value of lipid deposition of 9.40%. The values of ash, crude fibre, carbohydrate contents of the experimental fish did not show any particular trend of relationship with experimental diets. However, it was noted that water content of the experimental fish increased with decreasing body protein and body lipid.

Table 32 - Proximate body composition of the juvenile of C. nigrodigitatus fed on experimental diets

Parameters	Initial	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Crude protein (%)	68.45±0.24[a]	68.95±0.45[a]	68.84±0.21[a]	68.64±0.19[a]	68.50±0.20[a]	68.45±0.98[a]
% Fat	9.34±0.07[a]	12.48±0.09[b]	11.38±0.05[c]	10.21±0.20[d]	9.92±0.26[a]	9.40±0.01[a]
% ash	11.13±0.37	10.54±0.23	10.37±0	11.36±0.33	11.00±0.09	11.21±0.08
% moisture	10.01±0.05	7.00±0.03	7.69±0.04	8.00±0.05	9.31±0.06	9.60±0.03
% crude fibre	0.82±0.002	0.65±0.003	0.89±0.006	0.91±0.004	0.64±0.005	0.69±0.003
% carbohydrate	0.025±0.006	0.38±0.003	0.83±0.005	0.60±0.004	0.63±0.004	0.65±0.006
Total	100.00	100.00	100.00	100.00	100.00	100.00

Figures in the same horizontal row having similar superscript are not significanlty different at P>0.05.

Table 33: Mean values of water quality parameters in juveniles' experimental tanks

Parameter	Range	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Temperature(^{o}C)	24.50-26.50	25.60±0.50	25.50±0.30	26.20±0.30	26.10±0.10	25.60±0.20
Dissolved oxygen(mg/1)	6.80 - 7.60	7.40±0.20	7.10±0.50	7.15±0.35	7.00±0.20	6.95±0.13
pH	7.10-7.90	7.50±0.10	7.6 ± 0.10	7.4 ± 0.25	7.3 ± 0.20	7.5 ± 0.35

4.5.11 Results of the water quality parameters in juvenile's experimental tanks.

Table 33 shows the mean values of water quality parameters in the juvenile experimental tanks. There was a temperature range of 24.5 to 26.5°C. Dissolved oxygen ranged between 6.8 and 7.6 mg/l while the pH ranged from 7.1 to 7.7. The differences recorded in the mean values of water temp., pH and dissolved oxygen were not statistically significant ($P > 0.05$) within the dietary treatments.

4.6.0 Growth response and nutrient utilization parameters of adult males of C. nigrodigitatus

4.6.1 Weight changes (WTC) and weight gain (WTG)

The results of weight changes and the average weight gain of adult males of C. nigrodigitatus are presented in Table 34. The average initial weight of fish increased with increasing level of dietary protein. Diet 3 had the best gain in weight and diet 6 had the least weight gain. Statistically, there was no significant difference ($P > 0.05$) in the mean weight gain of fish fed on diets 3 and 4.

Table 34 - Weight changes (WTC) and weight gain (WTG)of adult males of C. nigrodigitatus fed on experimental diets

Growth Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
(WTC) Weight changes	Week 0	99.66±0.51^{a}	100.04±0.10^{a}	99.76±0.52^{a}	100.03±0.10^{a}	0.0934	n.s
	" 2	111.80±0.60^{a}	111.73±0.50^{a}	107.32±0.99^{b}	103.14±0.20^{c}	0.9364	*
	" 4	123.85±0.52^{a}	123.15±0.67^{a}	114.81±0.41^{b}	106.10±0.17^{c}	1.8666	*
	" 6	138.30±0.50^{a}	137.56±0.52^{a}	126.26±0.38^{b}	109.95±0.06^{c}	2.9632	*
	" 8	155.77±0.96^{a}	155.64±0.74^{a}	132.00±0.55^{b}	113.30±1.06^{c}	4.6006	*
(WTG) Weight gain	" 2	12.14±0.28^{a}	11.64±0.56^{a}	7.56±0.66^{b}	3.12±0.24^{c}	0.9448	*
	" 4	12.05±0.09^{a}	11.47±0.54^{a}	7.49±0.63^{b}	2.91±0.28^{c}	0.9516	*
	" 6	14.45±0.40	14.41±0.21^{a}	11.46±0.42	3.90±0.24^{c}	1.1141	*
	" 8	17.44±1.40	18.08±0.39^{a}	5.74±0.66^{b}	3.34±1.09^{c}	1.7351	*
	Mean	14.02±2.54^{a}	13.90±3.09^{a}	8.06±2.42^{c}	3.32±0.43^{c}	0.4713	*

Figures in the same horizontal row having similar superscript are not significantly different : ($P>0.05$).
* Significant ($P<0.05$). n.s. = Not significant. S.E. = Standard error.

The prediction equation relating weight gain (Y) to different dietary protein levels (Table 37) is Y = -5.03597 + 1.3696X, with r value of 0.9625. The result of correlation matrix in Table 42 shows that WTG was positively and highly correlated to all growth and nutrient utilization parameters except for FCR which was negatively but significantly correlated ($P < 0.05$).

4.6.2 Daily rate of growth (DRG)

The DRG increased with increasing dietary protein level (Table 35). Diet 3 had the highest value of 8.4×10^{-3} while diet 6 had the lowest value of 2.3×10^{-3}. Statistically, there was no significant ($P > 0.05$) difference between the mean values of diets 3 and 4.

All growth and nutrient utilization parameters except FCR were significantly and positively correlated to DRG. The regression equation relating DRG (Y) to different levels of dietary protein (X) is Y = -0.0023 + 0.0077X. Correlation coefficient (r) = 0.9649. (Table 41).

Table 35 - Daily rate of growth (DRG) and percentage weight gain (PWG) of C. nigrodigitatus adult males fed on experimental diets

Growth Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Dail rate of growth.							
DRG	Week 2	0.0087 ± 0.00022^{a}	0.0083 ± 0.00042^{a}	0.0054 ± 0.00048^{b}	0.0022 ± 0.00021^{c}	0.00068	*
	" 4	0.0075 ± 0.00022^{a}	0.0073 ± 0.00035^{a}	0.0050 ± 0.00046^{b}	0.0020 ± 0.00017^{c}	0.00058	*
	" 6	0.0084 ± 0.00025^{a}	0.0084 ± 0.00013^{a}	0.0071 ± 0.00025^{b}	0.0027 ± 0.00017^{c}	0.00061	*
	" 8	0.0090 ± 0.00073^{a}	0.0086 ± 0.00057^{a}	0.0032 ± 0.00040^{b}	0.0022 ± 0.00071^{c}	0.00081	*
	Mean value	0.0084 ± 0.00065^{a}	0.0082 ± 0.00058^{a}	0.0052 ± 0.0016^{b}	0.0023 ± 0.00030^{c}	0.00019	*
Percentage weight gain PWG	Week 2	12.18 ± 0.29^{a}	11.64 ± 0.57^{a}	7.57 ± 0.65^{b}	3.12 ± 0.24^{c}	0.9468	*
	" 4	10.78 ± 0.13^{a}	10.27 ± 0.49^{a}	7.00 ± 0.67^{b}	2.82 ± 0.27^{c}	0.8263	*
	" 6	11.67 ± 0.35^{a}	11.70 ± 0.22^{a}	9.98 ± 0.38^{b}	3.68 ± 0.23^{c}	0.8996	*
	" 8	12.61 ± 1.06^{a}	13.14 ± 0.28^{a}	4.55 ± 0.53^{b}	3.04 ± 1.000^{c}	1.1944	*
	Mean value	11.81 ± 0.79^{a}	11.69 ± 1.17^{a}	7.28 ± 2.23^{b}	3.19 ± 0.37^{c}	0.3017	*

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05).
* Significant (P<0.05) n.s. = Not significant. S.E. = Standard error.

4.6.3 Percentage weight gain (PWG)

The result is shown in Table 35. Diet 3 had the highest PWG while the lowest was observed in diet 6. Statistical analysis showed that there was no significant ($P > 0.05$) difference in the mean values of PWG of fish fed on diets 3 and 4. However, there were significant ($P < 0.05$) differences in the results of PWG of fish fed on other diets.

The regression analysis (Table 41) showed that there was a linear relationship between PWG (Y) and the dietary protein levels. The equation is $Y = -1.8761 + 0.9714X$. Correlation coefficient = 0.9289 correlation matrix (Table 42) showed that PWG was positively correlated with all measured parameters except for FCR which showed a negative correlation ($P < 0.05$).

4.6.4 Specific growth rate (SGR)

It was observed that SGR was influenced by dietary treatment. The highest value was observed in diet 3 and the lowest in diet 6 (Table 36). There was no significant difference ($P > 0.05$) between the SGR value of diet 3 and that of diet 4. The prediction equation relating

Table 36-Specific growth rate (SGR) of C. nigrodigitatus adult males fed on experimental diets

Growth Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Specific growth rate SGR	Week 2	0.82 ± 0.015^{a}	0.79 ± 0.03^{a}	0.52 ± 0.044^{b}	0.22 ± 0.016^{c}	0.0629	*
	" 4	0.73 ± 0.008^{a}	0.70 ± 0.033^{a}	0.48 ± 0.044^{b}	0.21 ± 0.013^{c}	0.05465	*
	" 6	0.79 ± 0.026^{a}	0.79 ± 0.016^{a}	0.68 ± 0.025^{b}	0.26 ± 0.014^{c}	0.05659	*
	" 8	0.85 ± 0.065^{a}	0.89 ± 0.019^{a}	0.32 ± 0.036^{b}	0.22 ± 0.071^{c}	0.07914	*
	Mean value	0.80 ± 0.05^{a}	0.79 ± 0.078^{a}	0.50 ± 0.148^{b}	0.23 ± 0.222^{c}	0.02007	*

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05).

* Significant (P<0.05) n.s. = Not significant. S.E. = Standard error.

SGR (Y) with different levels of dietary protein is: $Y = -0.2021 + 0.0722X$, $r = 0.9619$ (Table 41). The matrix in Table 42 shows that SGR was positively and significantly correlated with all measured parameters.

4.6.6 Gross food conversion efficiency (GFCE)

The result in Table 37 shows that GFCE is influenced by different levels of dietary protein. Diet 3 had the highest mean value of 28 while diet 6 had the lowest value of 7.53. Statistically, there was no significant difference ($P > 0.05$) in the mean GFCE values of fish fed on diets 3 and 4.

The equation relating GFCE (Y) with dietary protein levels (X) is given as $Y = -8.002 + 2.596X$, $r = 0.9595$ (Table 41). The result of correlation matrix (Table 42) showed that GFCE was significantly ($P < 0.05$) correlated with all growth and nutrient utilization parameters except for the FCR which was negatively correlated.

Table 37 - Gross food conversion efficiency (GFCE) and food conversion ratio (FCR) of adult males of C. nigrodigitatus fed on experimental diets

Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
GFCE Gross food conversion efficiency	Week 2	28.54 ± 1.37^{a}	27.72 ± 1.36^{a}	18.04 ± 1.55^{b}	7.42 ± 0.56^{c}	2.231	*
	" 4	25.66 ± 0.33^{a}	24.46 ± 1.16^{a}	16.63 ± 1.55^{b}	6.71 ± 0.65^{c}	1.9681	*
	" 6	27.78 ± 0.82^{a}	27.86 ± 0.51	23.76 ± 0.91^{b}	8.76 ± 0.55^{c}	2.0318	*
	" 8	30.00 ± 2.50^{a}	31.30 ± 0.64^{a}	10.84 ± 1.26^{b}	7.24 ± 2.37^{c}	2.8433	*
	Mean value	28.00 ± 1.81^{a}	27.84 ± 2.79^{a}	17.32 ± 5.31^{b}	7.53 ± 0.87^{c}	0.7131	*
Food conversion ratio (FCR)	Week 2	3.51 ± 0.17^{a}	3.62 ± 0.18^{a}	5.58 ± 0.48^{b}	13.53 ± 1.01^{c}	1.0688	*
	" 4	3.90 ± 0.051^{a}	4.10 ± 0.19^{b}	6.05 ± 0.56^{c}	15.01 ± 1.51^{d}	1.1887	*
	" 6	3.60 ± 0.11^{a}	3.59 ± 0.066^{a}	4.21 ± 0.16^{c}	11.45 ± 0.69^{d}	0.8613	*
	" 8	3.35 ± 0.27^{a}	3.20 ± 0.065^{b}	9.33 ± 1.07^{c}	15.04 ± 5.03^{d}	1.4264	*
	Mean value	3.59 ± 0.23^{a}	3.63 ± 0.37^{a}	6.29 ± 2.17^{b}	13.76 ± 1.69^{c}	0.2791	*

Figures in the same horizonatal row having similar superscript are not significantly different at ($P > 0.05$)

* Significant at ($P < 0.05$). n.s. = Not significant. S.E = Standard error.

4.6.7 Food conversion ratio (FCR)

The mean FCR values decreased with increasing level of dietary crude protein (Table 37). Thus diet 3 with the highest level of protein (30%) had the lowest FCR value of 3.59 while diet 6 with the lowest level of CP had the highest level of FCR value of 13.76.

The result of statistical analysis within the mean values showed that, FCR values in diets 3 and 4 were not significantly ($P > 0.05$) different. They were, however, significantly different from the values obtained in diets 5 and 6. The prediction equation relating FCR with different levels of dietary protein is given in Table 41 as: $Y = 19.7976 - 1.1963X$; correlation coefficient (r) is -0.9028. FCR was negatively significantly correlated with all measured parameters (Table 42).

4.6.8 Protein efficiency ratio (PER)

The result in Table 38 shows the mean values of PER for different diets. The highest mean PER value of 1.11 was obtained for fish receiving diet 4 followed closely were the fish receiving

diets 3 and 5 with mean PER values of 0.88 and 0.86 respectively. Diet 6 had the lowest PER value of 0.50. Statistically, the results of the mean values of PER in diets 3, 4 and 5 were not significantly ($P > 0.05$) different but were significantly higher than the mean value obtained in diet 6. Correlation matrix in Table 42 shows that PER was positively and significantly correlated with all growth and nutrient utilization parameters except for FCR which showed a negative but significant correlation ($P < 0.05$).

4.6.9 Nitrogen metabolism (Nm)

The mean values of Nm increased with increasing level of dietary crude protein (Table 38). Diet 3 had the highest mean value and diet 6 had the lowest mean value. Statistically, the results of Nm values in diets 3 and 4 were not significantly different ($P > 0.05$).

The equation relating Nm (Y) with different dietary protein (X) is : $Y = 19.3439 + 5.2632X$. The calculated r value is 0.9624 (Table 41). Table 42 shows the correlation matrix on growth and nutrient utilization parameters. Nm was positively and

Table 38 - Protein efficiency ratio (PER) and nitrogen-metabolism (Nm) of C. nigrodigitatus adult males fed on experimental diets

Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	SIG
PER Protein efficiency ratio	Week 2	0.74 ± 0.43^{a}	1.11 ± 0.051^{a}	0.90 ± 0.08^{b}	0.49 ± 0.04^{c}	0.07600	*
	" 4	0.86 ± 0.01	0.98 ± 0.04^{a}	0.80 ± 0.06	0.45 ± 0.04^{c}	0.05202	*
	" 6	0.93 ± 0.03	1.11 ± 0.03^{a}	1.19 ± 0.05^{b}	0.59 ± 0.04^{c}	0.06026	*
	" 8	1.00 ± 0.08	1.25 ± 0.03^{a}	0.54 ± 0.06	0.48 ± 0.16^{c}	0.08400	*
	Mean value	0.88 ± 0.11^{a}	1.11 ± 0.11^{a}	0.86 ± 0.27^{a}	0.50 ± 0.06^{b}	0.03531	*
Nitrogen metabolism Nm							
	Week 2	46.64 ± 1.09^{a}	44.74 ± 2.15^{a}	29.06 ± 2.50^{b}	11.98 ± 0.90^{c}	3.6307	*
	" 4	46.32 ± 0.36^{a}	44.09 ± 2.07^{a}	28.79 ± 2.42^{b}	11.18 ± 1.07^{c}	3.6568	*
	" 6	55.54 ± 1.56^{a}	55.38 ± 0.81^{a}	44.02 ± 1.60^{b}	15.02 ± 1.12^{c}	4.3006	*
	" 8	67.03 ± 5.39^{a}	69.48 ± 1.51^{a}	22.07 ± 2.55^{b}	12.85 ± 4.21^{c}	6.6682	*
	Mean	53.88 ± 9.75^{a}	53.50 ± 11.89^{a}	30.99 ± 9.27^{b}	12.76 ± 1.66^{c}	9.9097	*

Figures in the same horizontal row having similar superscript are not significantly different at ($P > 0.05$).

*Significant at ($P < 0.05$). n.s = Not significant S.E = Standard error.

significantly correlated ($P < 0.05$) with all measured parameters except for the FCR which showed a negative but significant ($P < 0.05$) correlation.

4.6.10 Cumulative growth response and nutrient utilization parameters of male adults of C. nigrodigitatus

The results of cumulative values for growth and nutrient utilization parameters are presented in Table 39. All cumulative values for each parameter increased with increasing levels of dietary protein. However, all the values for diets 3 and 4 were not significantly different ($P > 0.05$) but were significantly ($P < 0.05$) different for the other diets.

4.6.11 The productive protein value (PPV) or Apparent net nitrogen utilization (ANPU) of male adults of C. nigrodigitatus

The results of PPV or ANPU is presented in Table 39. Diet 3 with 30% crude protein level had value of 1.41, followed closely was diet 4 with a PPV value of 1.38. Diet 6 had the least PPV value of 0.38.

Table 39 - Cumulative Growth Response and Nutrient Utilization Parameters of C. nigrodigitatus adult males. fed on experimental diets

Parameters	Diet 3	Diet 4	Diet 5	Diet 6	S.E	SIG.
(WTG) weight gain	56.11±1.42^{a}	55.61±0.82^{a}	32.25±0.38^{b}	13.30±1.04^{c}	4.6136	*
(PWG) (Percentage weight gain)	56.50±2.18^{a}	55.45±1.08^{a}	32.33±0.46	13.30±1.04^{c}	4.6170	*
(SGR) Specific growth rate	0.80±0.022^{a}	0.79±0.0038^{a}	0.51±0.058^{c}	0.22±0.015^{c}	0.0614	*
(FCR) Food conversion ratio	3.56±0.12^{a}	3.57±0.044^{a}	7.56±0.11^{b}	16.94±1.34^{c}	1.4184	*
(GFCE) Gross food conversion efficiency	28.11±0.95^{a}	28.03±0.34^{a}	13.23±0.19^{b}	[illegible]±0.47^{c}	2.4815	*
(PER) Protein efficiency ratio	0.94±0.026^{a}	1.12±0.017^{a}	0.86±0.015	0.50±0.04^{c}	0.058	*
(Nm) Nitrogen metabolism	862.49±21.81^{a}	855.30±12.76^{a}	495.71±5.86^{b}	204.44±15.95^{c}	70.9497	*
PPV or Apparent NPU	1.31	1.14	0.80	0.038		

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* Significant at $P \leq 0.05$; n.s. = not significant; S.E = standard error.

4.6.12 Chemical composition of the body of adult males of C. nigrodigitatus fed on experimental diets.

The results of the chemical body composition of male adults is presented in Table 40. The initial body crude protein of 69.11% increased to the highest value of 69.95% in fish fed on diet 3, and fish fed on diet 5 had the lowest value of 69.21%. Statistically, the body protein content of fish was not significantly ($P > 0.05$) affected by dietary protein levels. However, the body lipid increased significantly ($P < 0.05$) with the increasing dietary protein level. The initial body lipid of 10.42% increased to the highest value of 15.47% in diet 3 and to the lowest value of 10.87 in diet 6.

The ash, crude fibre, and the carbohydrate contents of the experimental fish did not show any particular trend of relationship with the different levels of dietary crude protein. However, water content increased with decreasing level of body lipid.

Table 40 - Proximate body composition of the adult males of C. nigrodigitatus fed on experiment diets

Parameters	Initial	Diet 3	Diet 4	Diet 5	Diet 6	S.G
% crude protein	69.113±0.23	69.95±0.31	69.80±0.33	69.41±0.26	69.21±0.25	n.s
% Fat	10.42±0.15^{a}	15.47±0.91^{b}	15.30±0.29^{b}	12.98±0.21^{c}	10.87±0.09^{d}	sig
% Ash	9.34±0.05^{a}	7.22±0.28^{b}	7.31±0.04^{b}	8.71±0.03^{c}	9.68±0.1^{d}	"
% Moisture	9.53±0.07^{a}	6.26±0.03^{d}	6.31±0.08^{b}	7.46±0.04^{c}	8.51±0.003^{d}	"
% Crude fibre	0.921±0.005^{a}	0.60±0.002^{b}	0.68±0.004^{c}	0.84±0.002^{d}	0.93±0.003^{e}	"
% Carbohydrate	0.68±0.007^{a}	0.50±0.006^{b}	0.60±0.008^{c}	0.60±0.005^{c}	0.80±0.003^{d}	"

Figures in the same horizontal row having similar superscript are not significantly different (P>0.05)

* Significant (P<0.05). n.s. = Not significant. S.E. = Standard error.

Table 41 - Simple prediction equations, coefficients of determination and correlation coefficients relating each of the measured parameters to dietary protein levels in the adult males of C. nigrodigitatus

Dependent ^{Y} variables	Independent ^{X} variables	Prediction equation	r	R^2	S.E	SIG
WTG	Dietary protein level	Y = -5.03597+1.36967X	0.9625	0.9264	2.3041	*
DRG	"	Y = -0.00231+0.000768X	0.9649	0.9309	0.00129	*
SGR	"	Y = -0.2031+0.07218X	0.9619	0.9253	0.12149	*
PWG	"	Y = -1.8761+0.9714X	0.92698	0.8630	1.2478	*
FCR	"	Y = 19.7976-1.1632X	-0.9028	0.8150	2.1456	*
GFCE	"	Y = -8.0020+2.5967X	0.9595	0.9206	4.38195	*
Nm	"	Y = -19.3429+5.26317X	0.9625	0.9264	8.85396	*
PER	"	Y = 0.28117+0.05128X	0.7275	0.5428	0.112685	n.s

n.s = Not significant * Significant (P< 0.01)

Table 42 - Correlation matrix on growth responses and nutrient utilization parameters for C. nigrodigitatus adult males

Parameters	WTG	FCF	DRG	SGR	PWG	GFCE	FCR	PI	Nm	PER
WTG	1.0000									
FCF	0.65095*	1.0000								
DRG	0.95565**	0.42273 n.s	1.0000							
SGR	0.96627**	0.44811 n.s	0.99723**	1.0000						
PWG	0.96608**	0.44709 n.s	0.99752**	0.99995**	1.0000					
GFCE	0.96754**	0.45192 n.s	0.99724**	0.99992**	0.99993**	1.0000				
FCR	-0.89194**	-0.37689 n.s	-0.95155**	-0.94852**	-0.94879**	-0.94879**	1.0000			
PI	0.92262**	0.71928**	0.86219**	0.86471**	0.86559**	0.86559**	-0.79595**	1.0000		
Nm	0.9999**	0.65125*	0.95563**	0.96617**	0.96599**	0.96599**	-0.89185**	0.92263**	1.0000	
PER	0.86608**	0.44025 n.s	0.85915**	0.87162**	0.86948**	0.86948**	-0.87164**	0.63526**	0.86127**	1.0000

*Significant (P< 0.05) **Significant (P<0.01) n.s. = Not significant

Table 43: Mean values in the water quality parameters in male adult's experimental tanks

Parameter	Range	Diet 2	Diet 4	Diet 5	Diet 6
Temperature (°C)	23.5-26.0	24.80±0.50	25.30±0.30	24.70±0.60	25.30±0.70
Dissolved oxygen(mg/1)	7.0 - 8.1	7.50±0.30	7.60±0.50	7.30±0.30	7.5 ± 0.50
pH	7.4 - 7.8	7.0 ± 0.20	7.2 ± 0.20	7.4 ± 0.25	7.10±0.30

4.6.12 Result of mean values of measured water parameters in adult males' experimental tanks.

Table 43 shows the results of mean values of measured water parameter for each dietary group of adult males. The temperature ranged from 23.5 - 26.0°C. Dissolved oxygen was between 7.0 and 8.1mg/litre and pH ranged from 7.4 to 7.8. The differences recorded in the values of water temperature, pH and dissolved oxygen were not statistically significant.

4.7.0 Growth responses and nutrient utilization parameters of adult females of C. nigrodigitatus fed on experimental diets

4.7.1 Weight changes (WTC) and weight gain (WTG)

The results of weight changes and the average weight gain of the adult females of C.nigrodigitatus are presented in Table 44. The weight of fish increased significantly ($P < 0.05$) with increasing level of dietary protein. The best mean weight gain of 12.37 ± 1.73 gms was achieved with diet 2 containing 35% crude protein and the least value of 0.96±0.22gm was achieved with diet 6 containing 15% crude protein level.

Table 44 - Weight changes (WTC) and weight gain (WTG) of adult females of C. nigrodigitatus.

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Weight changes (WTC)	Week 0	100.52±0.69^{a}	100.03±0.25^{b}	100.55±0.23^{c}	99.95±0.27^{d}	100.21±0.15^{e}	0.2129	n.s
	" 2	114.37±0.22^{a}	112.06±0.07^{b}	109.46±0.21^{c}	105.57±0.17^{d}	101.38±0.16^{e}	0.0594	*
	" 4	128.40±0.42^{a}	123.50±0.50^{b}	117.32±0.54^{c}	110.01±0.04^{d}	102.05±0.09^{e}	0.2356	*
	" 6	139.05±0.08^{a}	132.31±0.50^{b}	122.86±0.19	113.84±0.07^{d}	103.11±0.15^{e}	0.1760	*
	" 8	149.98±0.32^{a}	139.95±0.23^{b}	129.25±0.12^{c}	116.05±0.06^{d}	104.03±0.12^{e}	0.1039	*
Weight Gain (WTG)	" 2	13.85±0.47^{a}	12.03±0.14^{b}	8.91±0.45^{c}	5.62±0.10^{d}	1.18±0.07^{e}	0.1971	*
	" 4	14.03±0.64^{a}	11.54±0.34^{b}	7.86±0.33^{c}	4.44±0.13^{d}	0.67±0.25^{e}	0.1886	*
	" 6	10.65±0.50^{a}	8.81±0.07^{b}	5.54±0.35^{c}	3.84±0.04^{d}	1.06±0.06^{e}	0.2089	*
	" 8	10.93±0.40^{a}	7.64±0.27^{b}	6.40±0.07^{c}	2.21±0.07^{d}	0.92±0.03^{e}	0.1600	*
	Mean value	12.37±1.73^{a}	10.00±1.95^{b}	7.18±1.41^{c}	4.02±1.32^{d}	0.96±0.22^{e}	0.6676	*

N.B. Figures in the same horizontal row having the same superscript are not significantly different ... (P > 0.05)

S.E = Standard error

* S.G = Significant at P < 0.05

n.s = not significant

The equation relating WTG (Y) with different levels of dietary protein (X) is given as: $Y = -5.1997 + 1.0135X$ (Table 51). The correlation coefficient (r) is 0.9969.

4.7.2 Percentage weight gain (PWG)

The percentage weight gain in the adult females of C. nigrodigitatus was significantly ($P < 0.05$) influenced by dietary protein levels (Table 45). It increased with increasing level of dietary protein. Diet 2 (35%CP) had the highest mean value of 10.55 ± 2.93 while diet 6 (15%CP) had least mean value of 0.94 ± 0.22.

The equation relating PWG with different levels of dietary protein as shown in Table 51 is: $Y = -4.1020 + 0.8511X$. The correlation coefficient (r) is 0.9948.

4.7.3 The specific growth rate (SGR)

The SGR values are presented in Table 45. The values increased significantly ($P < 0.05$) with increasing level of dietary protein. Thus, Diet 2 (35%CP) had the highest mean value of 0.72 ± 0.18 while diet 6 (15%CP)

Table 45 :- Percentage weight gains (PWG) and specific growth rate (SGR) of adult females of C. nigrodigitatus fed on experimental diets.

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Percentage weight gain (PWG)	Week 2	13.79±0.56^{a}	12.03±0.21^{b}	7.83±1.62^{c}	5.62±0.11^{d}	1.18±0.07^{e}	0.6477	*
	" 4	12.27±0.58^{a}	10.22±0.36^{b}	7.18±0.29^{c}	4.21±0.13^{d}	0.66±0.25^{e}	0.1666	*
	" 6	8.30±0.42^{a}	7.13±0.03^{b}	4.72±0.33^{c}	3.49±0.04^{d}	1.04±0.06^{e}	0.1847	
	" 8	7.87±0.29^{a}	5.78±0.22^{b}	5.21±0.07^{c}	1.94±0.07^{d}	0.89±0.03^{e}	0.1126	*
	Mean value	10.55±2.73^{a}	8.79±2.64^{b}	6.23±1.50^{c}	3.81±1.53^{d}	0.94±0.22^{e}	1.0248	*
Specific growth rate (SGR)	Week 2	0.93±0.00^{a}	0.82±0.05^{b}	0.62±0.03^{c}	0.40±0.05^{d}	0.07±0.00^{e}	0.0251	*
	" 4	0.83±0.02^{a}	0.69±0.03^{b}	0.50±0.00^{c}	0.29±0.00^{d}	0.04±0.007^{e}	0.0158	*
	" 6	0.57±0.06^{a}	0.51±0.01^{b}	0.33±0.05^{c}	0.23±0.03^{d}	0.08±0.007^{e}	0.0236	*
	" 8	0.54±0.07^{a}	0.40±0.04^{b}	0.37±0.00^{c}	0.12±0.03^{d}	0.06±0.00^{e}	0.0295	*
	Mean value	0.72±0.18^{a}	0.60±0.17^{b}	0.45±0.13^{e}	0.26±0.11^{d}	0.06±0.02^{e}	0.0638	*

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* Significant at $P < 0.05$.
n.s. = not significant.
S.E, = standard error.

Table 46 - Daily rate of growth (DRG) of the adult females of C. nigrodigitatus fed on experimental diets

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E
Daily rate of growth (DRG)	Week 2	$9.85^{-03}\pm3.54^{-04a}$	$8.6^{-03}\pm1.41^{-04b}$	$6.35^{-03}\pm3.54^{-04c}$	$4.05^{-03}\pm7.07^{-05d}$	$8.35^{-04}\pm7.07^{-06e}$	1.61^{-04}
	" 4	$8.8^{-03}\pm4.24^{-04a}$	$7.3^{-03}\pm1.28^{-03b}$	$5.15^{-03}\pm2.12^{-04a}$	$3.0^{-03}\pm1.4^{-04d}$	$4.65^{-04}\pm1.7^{-04e}$	4.80^{-04}
	" 6	$5.9^{-03}\pm2.83^{-04a}$	$5.1^{-03}\pm0.00^{b}$	$3.35^{-03}\pm2.12^{-04c}$	$2.5^{-03}\pm0.00^{d}$	$7.4^{-04}\pm4.2^{-05e}$	1.31^{-04}
	" 8	$5.65^{-03}\pm2.12^{-04a}$	$4.1^{-03}\pm1.41^{-04b}$	$3.7^{-03}\pm0.00^{c}$	$1.4^{-03}\pm0.00^{d}$	$6.35^{-04}\pm2.12^{-05e}$	9.65^{-05}
	Mean value	$7.6^{-03}\pm1.96^{-03a}$	$6.3^{-03}\pm1.90^{-03b}$	$4.6^{-03}\pm1.29^{-03c}$	$2.7^{-03}\pm1.02^{-03d}$	$6.7^{-04}\pm1.62^{-04e}$	7.35^{-04}

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* Significant at $P < 0.05$.
n.s = not significant.
S.E = standard error.

had the least mean value of 0.06 ± 0.02.

The prediction equation in Table 51 relating SGR to different dietary protein level is: Y = -0.2788 + 0.0583X. The correlation coefficient (r) is 0.9918.

4.7.4 Daily rate of growth (DRG)

The daily rate of growth (DRG) among the different dietary groups increased significantly ($P < 0.05$) with increasing level of dietary protein (Table 46). Diet 2 had the highest mean value of $0.0076 \pm 1.95 \times 10^{-2}$ and diet 6 had the lowest mean value of $0.00067 \pm 1.62 \times 10^{-4}$. The regression equation ralting.DRG with dietary protein levels is give as: Y = -2959 + 6.1397X, r = 0.9943(Table 51).

4.7.5 Food conversion ratio (FCR)

The result of FCR for the female adults of C. nigrodigitatus is presented in Table 47. There was a significant decrease ($P < 0.05$) in the mean FCR values with increasing level of dietary crude protein. Diet 2 had the best FCR value of 4.24 ± 1.17 and diet 6 had the poorest value of 48.03 ± 14.44.

Table 47 - Food conversion ratio (FCR) and Gross food conversion efficiency (GFCE) of adult females of C. nigrodigitatus fed on experimental diets

Parameter	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Food conversion ratio (FCR)	Week 2	3.05±0.13	3.50±0.06	4.75±0.25	7.47±0.16	35.82±0.16
	" 4	3.43±0.16	4.12±0.15	5.87±0.25	10.01±0.32	68.50±26.2
	" 6	5.28±0.04	5.89±0.01	8.91±0.61	12.02±0.09	40.5±2.12
	" 8	5.35±0.20	7.28±0.28	8.28±0.19	21.69±0.08	47.31±1.82
	Mean value	4.24±1.17	5.20±1.72	7.22±1.81	12.80±6.21	48.03±14.44
Gross food conversion efficiency (GFCE).	Week 2	32.82±1.36	28.62±0.52	21.11±1.10	13.39±0.28	2.79±0.01
	" 4	29.23±1.39	24.32±0.88	17.07±0.71	10.00±0.31	1.57±0.59
	" 6	18.94±0.16	16.98±0.04	11.25±0.76	8.30±0.07	2.47±0.13
	" 8	18.70±0.69	13.75±0.53	12.09±0.28	4.61±0.01	2.12±0.08
	Mean value	24.92±7.20	20.92±6.70	15.38±4.60	9.07±3.65	2.24±0.52

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* Significant at $P < 0.05$.
n.s = not significant.
S.E = standard error.

The prediction equation in Table 51 relating FCR (Y) with different dietary protein levels (X) is: Y = 54.831 - 3.2931X. The correlation coefficient (r) is -0.7991.

4.7.6 Gross food conversion efficiency (GFCE)

The result of GFCE is presented in Table 47. The values increased significantly ($P < 0.05$) with the increasing level of dietary crude protein. Diet 2 had the best mean value of 24.92 ± 7.20 and diet 6 had the poorest mean value of 2.24 ± 0.52.

The equation relating GFCE (Y) with dietary protein levels (X) is: Y = -9.5132 + 2.0191X. The correlation coefficient (r) is 0.9926 (Table 51).

4.7.8 Protein efficiency ratio (PER)

The result of PER presented in Table 48 shows that PER values increased significantly (P 0.05) with increasing levels of dietary protein. It was highest in diet 2 with a mean value of 0.72 ± 0.20 and lowest in diet 6 with a mean value of 0.15 ± 0.04. The equation relating PER (Y) with dietary protein (X) is: Y = 0.0444 + 0.0474X, coefficient (r) is: 0.9190(Table 57).

Table 48 - Protein efficiency ratio (PER) and Nitrogen metabolism (Nm) of adult females of C. nigrodigitatus

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Protein efficiency ratio (PER)	Week 2	0.94 ± 0.04^{a}	0.88 ± 0.09^{b}	0.84 ± 0.0^{c}	0.67 ± 0.01^{d}	0.19 ± 0.00^{e}	0.0383	*
	" 4	0.84 ± 0.02^{a}	0.81 ± 0.02^{b}	0.68 ± 0.03^{c}	0.50 ± 0.01^{d}	0.11 ± 0.04^{e}	0.0114	*
	" 6	0.56 ± 0.03^{a}	0.56 ± 0.007^{b}	0.45 ± 0.03^{c}	0.41 ± 0.00^{d}	0.17 ± 0.001^{e}	0.0139	*
	" 8	0.54 ± 0.02^{a}	0.45 ± 0.007^{b}	0.50 ± 0.007^{c}	0.23 ± 0.01^{d}	0.14 ± 0.01^{e}	0.0054	*
	Mean value	0.72 ± 0.20^{a}	0.67 ± 0.20^{b}	0.62 ± 0.18^{c}	0.45 ± 0.18^{d}	0.15 ± 0.04^{e}	0.0678	*
Nitrogen metabolism (Nm)	Week 2	52.36 ± 1.76^{a}	45.46 ± 0.67^{b}	33.66 ± 1.68^{c}	21.25 ± 0.37^{d}	4.44 ± 0.03^{e}	0.7808	*
	" 4	53.03 ± 2.4^{a}	43.27 ± 1.58^{b}	29.69 ± 1.26^{c}	16.77 ± 0.50^{d}	2.52 ± 0.94^{e}	0.7164	*
	" 6	40.23 ± 1.87^{a}	33.28 ± 0.30^{b}	20.95 ± 1.34^{c}	14.50 ± 0.15^{d}	4.01 ± 0.21^{e}	0.7872	*
	" 8	41.32 ± 1.49^{a}	28.88 ± 1.02^{b}	24.19 ± 0.27^{c}	8.34 ± 0.02^{d}	3.48 ± 0.11^{e}	0.6427	*
	Mean value	46.74 ± 6.90^{a}	37.72 ± 7.92^{b}	27.12 ± 5.66^{c}	15.22 ± 5.37^{d}	3.61 ± 0.85^{e}	2.7172	*

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* significant at $P < 0.05$.
n.s = not significant.
S.E = standard error.

4.7.9 Nitrogen metabolism (Nm)

The result of Nm for the adult females of C. nigrodigitatus is presented in Table 48. The mean Nm values increased significantly with increasing level of dietary protein. Thus, diet 2 had the highest mean value of 46.76 ± 6.90 while diet 6 had the lowest mean value of 3.61 ± 0.83. The equation relating Nm(Y) with different dietary protein levels (X) is given as: $Y = -19.6336 + 3.8275X$. The correlation coefficient (r) is: 0.9970.

4.7.10 Cumulative growth response and nutrient utilization parameters of female adults

The results of cumulative growth and nutrient utilization parameters over the eight weeks of feeding trials are presented in Table 49. All tested parameters increased significantly ($P < 0.05$) with the increasing level of dietary protein. Thus diet 2 containing 35% crude protein had the best mean values, while diet 6 with 45% crude protein had the poorest mean values.

Table 49 - Cummulative growth response and nutrient utilization parameters of female adults of C. nigrodigitatus on experimental diets.

Parameters	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	SIG
WTG	49.46±1.82^{a}	40.02±2.12^{b}	28.71±1.50^{f}	16.10±1.42^{d}	3.82±0.22^{e}	0.7239	*
PWG	42.23±2.93^{a}	35.16±2.85^{b}	24.93±1.50^{e}	15.26±1.55^{d}	3.77±0.22^{e}	1.1223	*
SGR	2.87±0.19^{a}	2.41±0.18^{b}	1.82±0.13^{c}	1.04±0.11^{d}	0.24±0.02^{e}	0.0680	*
DRG	0.03±0.002^{a}	0.025±0.002^{b}	0.019±0.0014^{c}	0.01±0.0011^{d}	0.0027±0.0002^{e}	0.0008	*
GFCE	99.69±7.20	83.67±6.78	61.52±4.60	36.30±3.65	8.94±0.52	2.694	*
FCR	4.10±1.15^{a}	4.91±1.65^{b}	6.59±1.78^{c}	11.20±5.20^{d}	44.69±11.24^{e}	4.2491	*
PER	0.70±0.20^{a}	0.68±0.20^{a}	0.61±0.18^{a}	0.45±0.18^{b}	0.15±0.04^{c}	0.0678	*
Nm	186.94±6.90^{a}	150.89±7.93^{b}	108.49±5.66^{c}	60.86±5.37^{d}	14.45±0.82^{e}	2.7237	*
FCF	202.59±7.04	196.53±5.88	189.14±4.07	180.34±2.51	170.70±0.50	2.6101	*
PI	70.90±2.47	58.96±1.78	47.28±1.02	36.08±0.50	25.62±0.08	0.9646	*
PPV or ANPU	0.008	0.003	0.0009	-0.001	-0.002	-	n.s

Figures in the same horizontal row having similar superscript are not significantly different at $P > 0.05$.

* significant at $P < 0.05$.
n.s = not significant
S.E = standard error.

4.7.11 Productive protein value (PPV)

The productive protein value decreased significantly ($P < 0.05$) from 0.008 in fish fed on the highest level of crude protein (35%) to -0.002 on the fish fed on the lowest level of dietary protein (15%) (Table 49).

4.7.12 Chemical composition of the body of adult females fed on experimental diets.

The result of the chemical composition of the body of adult females is presented in Table 50. The body protein content was not significantly ($P > 0.05$) affected by dietary protein levels. The body lipid was however, significantly affected by dietary protein levels. It increased significantly ($P < 0.05$) with increasing level of dietary protein. The initial body lipid of 13.46% increased to the highest level of 14.60 in diet 2 and to the lowest value of 13.50 in diet 6.

The crude fibre, total ash and carbohydrate contents of the fish did not show any trend of relationship with increasing level of dietary protein. Water content increased with decreasing level of body lipid.

Table 50 - Proximate body composition of the female adults of C. nigrodigitatus on experimental diets

Parameters	Initial	Diet 2 35% crude protein	Diet 3 30% crude protein	Diet 4 25% crude protein	Diet 5 20% crude protein	Diet 6 15% crude protein	S.G
% crude protein	65.23±0.65^{a}	65.20±0.55^{a}	65.40±0.71^{a}	65.27±0.60^{a}	65.19±0.50^{a}	65.17±0.59^{a}	n.s
% crude fat	13.46±0.25^{a}	14.60±0.20^{b}	14.10±0.15^{c}	13.82±0.11^{d}	13.65±0.08^{e}	13.50±0.10^{f}	*
% moisture	7.65±0.13^{a}	6.15±0.08^{b}	6.45±0.10^{c}	7.10±0.08^{d}	7.50±0.10^{e}	7.60±0.09^{f}	*
% ash	12.28±0.25^{a}	12.10±0.11^{b}	12.26±0.13^{a}	11.36±0.09^{c}	11.96±0.12^{d}	12.00±0.07^{b}	*
% crude fibre	1.28±0.02^{a}	1.04±0.04^{b}	1.20±0.05^{c}	1.30±0.05^{a}	0.98±0.04^{b}	1.10±0.01^{b}	*
% Carbohydrate	1.10±0.07^{a}	0.98±0.04^{a}	0.99±0.05^{a}	1.21±0.08^{b}	1.00±0.07^{a}	0.78±0.15^{c}	*

Figures in the same horizontal row having the same superscript are not significantly different ($P > 0.05$).

* Significant ($P < 0.05$) S.E. = Standard error.

Table 51 - Prediction equations and correlation coefficients relating each of the measured parameters to dietary protein levels in the adult females of C. nigrodigitatus.

Dependent variables (V)	Independent Variables (X)	Prediction equation	r	R^2	S.E	SIG
WTG	Dietary protein levels	Y = -5.1997+1.0135X	0.9969	0.9938	4.5603	*
PWG	"	Y = -4.1020+0.8511X	0.9948	0.9896	3.8379	*
SGR	"	Y = -0.2788+0.0583X	0.9918	0.9837	0.2639	*
DRG	"	Y = $-2.959^{-03}+6.197^{-04}X$	0.9943	0.9886	0.0028	*
FCR	"	Y = 54.83-3.2931X	0.7991	0.6386	18.4860	*
GFCE	"	Y = -9.5132+2.0191X	0.9926	0.9853	9.0879	*
PER	"	Y = -0.0444+0.0474X	0.9190	0.8445	0.2315	*
Nm	"	Y = -19.6336+3.8275X	0.9970	0.9880	17.2210	*

*SIG = significant at $P \leq 0.05$.
S.E = standard error.

Table 52: The correlation matrix on growth responses and nutrient utilization parameters of adult females of C. nigrodigitatus

	FCF	P I	WTC	WTG	PWG	DRG	SGR	FCR	PER	NM
FCF	1.0000									
P I	.9940*	1.0000								
WTC	.9977*	.9943*	1.0000							
WTG	.9974*	.9963*	.9997*	1.0000						
PWG	.9967*	.9922*	.9998*	.9992*	1.0000					
DRG	.9968*	.9922*	.9998*	.9992*	1.0000	1.0000				
SGR	.9968*	.9907*	.9996*	.9987*	.9999*	.9999*	1.0000			
FCR	.8441*	.7921*	.8445*	.8327	.8527*	.8535*	.8575*	1.0000		
PER	.9501*	.9157*	.9516*	.9443	.9563*	.9566*	.9596*	.9622*	1.000	
NM	.9974*	.9963*	.9997*	.9000	.9992*	.9992*	.9987*	.8328*	.9443*	1.000

*Significant at $P < 0.01$.

4.7.13 Results of water quality parameters in the adult females' experimental tanks

The result of water quality parameters for the culture media of female fish is presented in Table 49. The water temperature ranged from 24.0 - 26.50^{o}C; the dissolved oxygen ranged from 6.80 - 8.20. The pH ranged between 7.0 - 7.7. There were no statistical differences ($P > 0.05$) in all the measured parameters within the dietary groups.

Table 53: Mean values of water quality parameters in the adult females' experimental tanks.

Parameter	Range	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Temperature (^{o}C)	24.0-26.5	25.5±0.50	25.7±0.40	26.0±0.50	25.80±0.30	25.40±0.50
Dissolved oxygen mg/l	6.80-8.20	7.50±0.20	7.70±0.50	7.00±0.80	7.2 ± 0.40	7.80±0.40
pH	7.0 ± 7.7	7.2 ± 0.20	7.4 ± 0.30	7.1 ± 0.40	7.50±0.50	7.2 ± 0.20

Chapter 5

5.0 Discussion

5.1 Reproduction in C. nigrodigitatus

5.1.1 Size at maturity and sex-ratio

On the basis of length, females of C. nigrodigitatus reached maturity earlier in terms of size than males. Similar observation was made for Oreochromis nilotica by Babiker and Ibrahim (1979). It however contradicted the report of Lagler et al, (1962) that males mature at a smaller size than the females. Thompson, (1963) noted that smallest minimum sizes at maturity have been recorded for warm water species and greatest size for cold water species.

The observation that females were more abundant in the first half of the year than the males, might be attributed to sampling intensity or reproductive preparations. As there were more females than males during the spawning season. This finding is similar to the observation of Ezenwa (1981) on the sex ratio of C. nigrodigitatus in Badagry lagoon. Babikar and Ibrahim (1979) had earlier observed differences in the sex ratio

of Tilapia nilotica during reproduction.

5.1.2 Egg sizes and fecundity

In this study the egg diameters for C. nigrodigitatus ranged from 2.95 to 3.50 with a mean of 3.20 ± 0.25. This value is within the range of 2.65 to 4.00 mm observed by Imevbore (1970) in C. nigrodigitatus at River Niger and that given by Fagade and Adebisi (1979) as 2.35 to 3.70 in Asejire lake. The mean egg size of 3.20 mm is however bigger than that of C. nigrodigitatus in Badagry lagoon given as 2.50 mm by Ezenwa (1981). It is also bigger than those of some other species of Chrysichthys as reported by Imevbore(1970) who observed a mean egg diameter of 2.61 mm for C. auratus longifilis and Ikusemiju (1976) who recorded a mean egg diameter of 2.10 mm for C. walkeri.

The number of eggs recorded for each of the paired ovaries varied from 254 to 1,138. These values are lower than those reported by Imevbore (1970) in C.nigrodigitatus and C. auratus longifilis from River Niger as 18,740 and 34,200 eggs respectively. The values are also lower than those recorded for C. nigrodigitatus by Ezenwa (1981) as 11,745 eggs in Badagry lagoon, 15,546 eggs in Warri river

and 14,088 eggs in Imo river. The fecundity estimates in this study is comparable to the fecundity range of 189 to 2,884 reported by Fagade and Adebisi (1979) for C. nigrodigitatus in Asejire dam.

The calculated correlation coefficients of 0.50 for fecundity/body weight and 0.55 for fecundity/ standard length in C. nigrodigitatus show that both the body weight and standard length are significantly correlated to fecundity. The high value of correlation coefficient of 0.97 for fecundity/ovary weight shows that ovary weight is highly correlated to fecundity and can be used as a more reliable indicator for fecundity than body weight or length. Fagade and Adebisi(1979) observed significant correlation coefficients of 0.78 for fecundity/body weight and 0.67 for fecundity/standard length in C. nigrodigitatus in Asejire lake. These correlation values are higher than those reported in this study.

In general, the large egg sizes of C.nigrodigitatus and the observed low fecundities indicated that fish exhibited some degree of parental care in accordance to the report of Fryer (1959), Lagler et al, (1962); and Nikolsky (1963) that the sizes of eggs of fish are directly related to the amount of care the fish can give to its young ones. Fagade and Adebisi (1979) had also indicated that Chrysichthys nigrodigitatus probably exhibited some degree

of parental care. Further, the observed one-sized group of bright yellow ova suggested that C. nigrodigitatus spawn only once. Qasim and Qayyum (1961); Chan and Chua (1980) had earlier reported that fishes having a single batch of maturing eggs spawn only once with a short breeding season.

5.1.3 Monthly variation in the GSI, HSI, and K of C. nigrodigitatus

The wide range in the monthly variation of GSI (Table 8) of C. nigrodigitatus probably suggests that spawning occurs throughout the year with a peak activity in March to April and possibly May. During the off-seasons, fish with mature ovaries were caught and this also reflect the potential of the fish to breed throughout the year.

Ikusemiju (1976) on C. walkeri in Lekki lagoon observe that the fish breed most of the year from September to June with a peak spawning in March, and that specimens with ripe ova were caught during most months of the year. Ajayi (1972) in Kainji lake, reported that C. auratus spawn between June and October. Fagade and Adebisi (1979) observed that C. nigrodigitatus in Asejire lake spawns between April and October with a peak in June and July. Ezenwa (1981) observed that C. nigrodigitatus in Badagry lagoon spawns in December.

However, the monthly mean values of GSI of the fish can be used to determine the reproductive phases/ stages of fish hence its reproductive cycle. According to Al-Daham and Bhatti (1979) classification; the gonad preparatory stage or growth phase is when there is steady increase in the GSI values. The prespawning phase or maturing stage is when there is a sharp increase in GSI values. The spawning phase/ stage, when there is a sharp drop in the mean value of GSI. The resting phase or post spawning phase; when the GSI value is at its minimum, indicating that most of the fish have spawned.

On the basis of above classification therefore, the reproductive cycle of C. nigrodigitatus females was traced and divided into four distinct phases. The preparatory phase or growth phase occurred between September and December, when GSI increased gradually from 5.89 to 6.60. The prespawning phase or maturing phase was between January and February when GSI increased sharply to values of 9.40 and 9.69. The spawning stage was between March and April and possibly May, when the GSI value declined to about 6.00. The resting phase occurred in June to August

when the GSI reached its minimum value of about 3.15. In the males, two distinct reproductive phases were traced. These were the preparatory phase or growth phase which occurred between July and February. The spawning phase occurred between March and May.

The observed spawning period of March to April possibly May, coincided with the periods of high temperature and low rainfall when there was low food supply. It is not unlikely, therefore, for the fish to reserve food in its body or organs during the period of high food supply which would latter be used for gonadal maturation and spawning activities.

The low HSI and K values during the spawning season showed that there were relative depletion of food reserves from the carcass and liver during the spawning period, thus supporting the above stipulation. Htun-Han (1978) had earlier reported a fall in HSI in Limanda limanda during the spawning period. And Scott (1974); in Mormyrus kannume observed that the highest HSI occurrs at the onset of breeding season and a sharp drop during the breeding season. Winfield and Grimm (1977) showed that in the Irish sea place, Pleuronectes platessa, HSI is lowest in the post-spawning period.

5.1.4 Changes in GSI, HSI and K at different stages of gonadal development

The increase in GSI with the progressive development of the gonads in both male and female until the gonads were ripe (stage IV) and the sharp decline at spawning and spent fish, conforms with the normal pattern of development of most teleostean fish (Babiker and Ibrahim 1979; Al-Daham and Bhatti 1979; Dodd 1977; and Zuckerman and Baker 1977). The increase in GSI during the period of gonad maturation according to Htun-Han (1978) is mainly due to deposition of large amounts of proteins and lipids in the developing eggs and spermatozoa. These nutrients come from ingested food and from reserves of food deposited during active feeding season (Shul'man 1974; Larson 1974 and Iles 1974).

The lower GSI values of males of C. nigrodigitatus compared to those of the females might be due to the small size of the tests. Similar observation was made by Wootton 1985 in Sticklebacks (Gasterosteus aculeatus).

5.1.4.2 Changes in HSI at different stages of gonadal development

The increase in HSI values as the ovary weight increased (stages I - IV) and remained relatively high at spawning (stage V) showed that the reserves in the liver were not depleted during the process of egg formation and that female of C. nigrodigitatus continued feeding and storing up fat in the liver during the process of gonadal growth and maturation. These findings are in agreement with the work of Smith et al. (1990) who reported that the highest liver index in the females of Pacific cod coincides with maximum gonad development. Htun-Han (1978); reported that liver reserves in female dab Limanda limanda are not seriously depleted during yolk formation. And Lee (1972) found that dab Limanda limanda continues feeding during the period of gonad maturation.

The decrease in the HSI at gonadal maturation (Stage IV) and at spawning (stage V) in the male of C. nigrodigitatus showed that energy was depleted from the liver for the final maturation of the testes; for the development of secondary sexual

characters and for spawning activities. A similar finding has been reported by Wootton (1985) for the male of sticklebacks Gaterosteus aculeatus.

The increase in the HSI of male of C. nigrodigitatus after spawning showed that the fish fed actively immediately after spawning. In general, the female of C. nigrodigitatus stored up fat in its liver throughout the period of ovarian development and this reserve was depleted immediately after spawning probably for parental activities. In the males, however, the fat reserve in the liver was depleted for the maturation of testes, and for spawning activities.

5.1.3.3 Changes in condition factor (K) at different stages of gonadal development

The decrease in the condition factor (K) in the male of C. nigrodigitatus during spawning (gonadal stage V) indicated that the carcass was also depleted for spawning activities. In the female fish, however, the decrease in the condition factor (K) during the final maturation of the ovaries, (stage IV) and at spawning (stage V) and immediately after spawning

(stage VI) showed that the carcass was depleted for ovarian maturation, spawning activities and for parental care of the eggs and newly hatched. These findings agree with the work of Gupta (1974) in Mormyrus armatus and Smith et al. (1990) in Pacific cod. In general the condition of C. nigrodigitatus was affected by reproductive cycle. Jones (1970) had earlier concluded in his study of reproductive biology of turbot, Scophthalmus maximum that K is closely linked to reproductive cycle.

5.1.4 Changes in the lipid, protein, ash and energy contents of the carcasses, liver, and ovaries of C. nigrodigitatus at different stages of gonadal development

5.1.4.1 Changes in the lipid contents of the carcass, liver and ovaries

The gradual increase in the total body lipid and liver lipid of both males and females of C. nigrodigitatus at the initial phase of gonad development (stages I to III) showed that the developing gonads were still small, and that the feeding of the fish was in excess of their lipid requirements. This

observation is in agreement with the work of Bogoyavlenskaya et al. (1975) who reported that in Gadus callarias the initial period of gonadal growth is accompanied by an increase in both body and liver weights. This has also been reported by Turuk (1972) in Gadus morhua. Generally, the females of C. nigrodigitatus accumulated more lipid in their bodies than the males before the final maturation of the gonads, suggesting that females consumed additional food than males to meet the energy demand for ovarian maturation. This is supported by the work of Turuk (1972) in Gadus morhua and the work of Ackman et al, (1969) in female of Mallotus villosus.

At the final maturation of the gonads (stage IV), howevever, the lipid requirement of C. nigrodigitatus outstripped the available food intake, so that the reserve in the muscle of the female and that in the liver of the male were catabolised to provide the necessary energy requirement for the gonadal maturation. This showed that the pattern of lipid utilization for the maturation of gonads differed between sexes. This observation agrees with the report of Bogoyavlenskiaya and Vel'tishcheva (1972) in Gadus

callarus. They reported that the females withdraw mostly lipid from their bodies while the males withdraw lipid from the liver, Shatunovskii and Novokov (1971) reported that more lipid is removed from the muscle of female Salmo trutta than males as gonadal maturation advances. The lipid of the liver in the female of C. nigrodigitatus however suffered a sharp loss immediately after spawning (gonadal stage VI) indicating that liver of female of C. nigrodigitatus had initially acted as storage organ throughout the periods of gonadal development and spawning, and was thereafter depleted during the period of parental activities when the carcass or muscle lipid was still in its state of recovering.

The lipids of the eggs in gonadal stages III to V were fairly constant showing that they were insulated from the effects of fluctuations in the food supply. This strategy ensures adequate food supply for the future larvae.

5.1.4.2 Changes in the energy content of the carcass, and eggs at different stages of gonadal development

The increase in body energy content of both males and females of C. nigrodigitatus at the initial period of gonadal growth (stages I to III) revealed the C. nigrodigitatus did not only feed for routine metabolism but also laid down energy reserves. This has been supported by Shul'man (1974) that some species of fish support gonadal growth with accumulated energy stores.

The sharp decline in the energy content of the soma at the final maturation of the gonads indicated that the energy cost for the maturation of the ovaries was greater than the energy intake, energy was therefore, mobilized from the reserves made by the body. This pattern of energy transfer from the soma to the ovaries showed that C. nigrodigitatus had regulatory mechanisms over energy partitioning between the ovaries and soma; and that the fish was not helpless in the face of low energy intake during the period of gonadal maturation. It stands to reason, therefore, that C. nigrodigitatus has the ability to control the timing of her gonadal maturation even in the face of low food

supply, if all other environmental factors are suitable. This pattern of reproductive strategy has been reported for the females of Sticklebacks Gasterosteus aculeatus by Wootton (1985).

The energy costs of forming ripe ovary could be estimated from the difference between the total energy content of the body of the fish at gonadal stage III and the total energy content of the body of the fish at gonadal stage IV. This showed a net decrease of about 50 kcal and a substantial portion of this was gained for the final ripening of the eggs.

5.1.4.3 Changes in the protein and ash contents of the carcass, liver and ovaries of C. nigrodigitatus at different stages of gonadal development

The greater total protein content of the liver of female of C. nigrodigitatus compared to the liver of the males (Table 6) during gonadal development has also been reported by Medford and Mackay (1978) in Northern Pike Esox lucius. The differences in liver protein between sexes according to Medford and Mackay (1978) is difficult to interpret. But it may be due

to the increased amount of enzyme required for vitellogenesis or may be related to the storage of yolk constituents or their precursors. In both sexes of C. nigrodigitatus the levels of both body and liver protein remained fairly constant throughout the period of gonadal development. This showed that fat reserves were the main source of energy. This observation according to Hails (1983) is common with many other species of fish.

The increase in ash content in the carcasses of both sexes at the maturation of the gonads and its reduction during spawning showed that spawning activities were associated with high mineral loss.

5.2.0 Semi-artificial spawning and larval rearing of C. nigrodigitatus

5.2.1.0 Semi-artificial spawning in C. nigrodigitatus

The spawning of C. nigrodigitatus in bamboo tubē shows the importance of appropriate substrate to induce spawning in this species. This agrees with the work of Stancey (1985) who reported that some species of fish can rapidly be induced to spawn in the presence of appropriate substrate. Woynarovich and Horvath (1980) had earlier reported that spwaning receptacles like milk cans or oil barrels placed in a hiding place stimulated

spawning in Channel catfish Ictalurus punctatus. They reported further that pipes of large diameters made of clay, plastic or cement could be used to stimulate spawning in Clarias batrachus and other catfishes. Hem (1985) observed that C. nigrodigitatus was stimulated to spawn when gravid male and female were paired in a plastic PVC tube placed in Lasjo lagoon in Ivory coast.

The observation that C. nigrodigitatus did not spawn inside the concrete tank despite the specificity of substrate (bamboo tube) probably suggests that substrate specificity alone will not stimulate spawning in C. nigrodigitatus. It also shows that the fish may not spawn in a static water environment.

In the present study, the totality of the observed environmental conditions, viz: mean water temperature of 22.8 ± 0.22°C; dissolved oxygen of 7.20 ± 0.44 mg/l, pH 6.94 ± 0.23; suitable spawning substrate (bamboo tube), direct contact with gravid partner; absence of light and a gentle flow of water across the spawning substrate stimulated spawning in C.nigrodigitatus. However, the relative importance of each of these factors which determine spawning still remains unidentified and this is recommended for future research.

5.2.1.1 Larval development/larval rearing

The observed developmental stages of C.nigrodigitatus larvae followed the normal pattern described by Blaxter (1969) in Hoar and Randall (1969) of teleostean. But differed in certain aspects when compared to some other species. The mean total length of 6.65 mm of newly hatched larvae of C. nigrodigitatus is relatively longer than that of Clarias gariepinus of 5.48 mm (Bammimore 1989); and those of T. zilli of 3.43mm and 4.84mm in S. niloticus(Omotosho 1985). Generally,Blaxter(1969)and Ciechomski(1966)had related the length of larvae at hatching to incubation temperature, incubation period and the size of eggs. In C. nigrodigitatus the relatively larger size of eggs of mean diameter of 3.20 mm compared to 1.18 mm in Clarias gariepinus (Bamimore 1989), 1.19 mm in T. zillii and 1.13 mm in S. niloticus (Omotosho 1985) may be an important factor affecting its size at hatching.

The hatching time of 48 - 50 hours after fertilization in C. nigrodigitatus was more prolonged when compared with the hatching time of 24 hours after fertilization in Clarias gariepinus (Brit and Hecht 1987). The observed differences in the hatching time might be due to egg sizes species differences and incubation temperature. Brit and Hecht (1987) recorded an incubation temperature of 25°C, i Clarias gariepinus compared to an incubation temperature

23.1°C ± 0.45°C recorded in this study.

The increase in the average total length of larvae and the proportional decrease of yolk sac diameter showed that the larvae used the endogenous food reserve for growth and development. The yolk sac of C. nigrodigitatus was completely utilized on the 10th day of hatching. In Clarias gariepinus according to Bammimore (1989) the yolk sac was utilized completely on the 5th day. The longer period of yolk sac utilization in C. nigrodigitatus was because of the bigger size of eggs. The importance of large egg size has been reported by Nikolsky (1963); Fryer and Iles, (1972). It contributes to the survival of larvae

The sharp drop in the weight of larvae towards the end of yolk-sac absorption showed that the remaining amount of yolk reserves was not enough for the development and growth of the larvae. During this time the larvae accepted external food (live plankton), since the larvae had developed functional eyes and mouth and were capable of moving freely in water. The acceptance of live food during this stage of larval development according to Lasker et al 1970 and Kuo et al (1973) would prevent mortality from irreversible starvation.

Bagenal (1969) reported reduced growth rate and shrinkage of larvae fish towards the end of yolk sac absorption and recommended the immediate feeding of the larvae to avoid total mortality. The acceptance of live plankton before the complete utilization of yolk sac in C. nigrodigitatus has also been reported for many species (Cadwallader, 1976, Benzie 1968 and Kennedy 1969).

Two critical periods involving high mortalities were clearly indicated during the 10 days of endogenous feeding. The first high mortality rate of 9.15% and 9.46% occurred on the 3rd and 4th day respectively, and this period coincided with the opening of the mouth. The second high mortality of 14.26 and 13.49% occurred on the 7th and 8th day respectively, when the yolk of the larvae was in the rudimentary stage, and could not cope with the growth and development of the larvae. The two critical periods accounted for 46.40% of the total mortalities of 62.22%. Many workers have reported critical periods of high mortalities during the early larval development and during the weaning stage from the endogenous feeding to exogenous feeding (Liao et al, 1971; Kuo et al, 1973; Nickum 1978 and Hansen and

Borrensen 1989).

The results of the water quality parameters showed that the spawning, hatching and rearing operations were carried out under optimum conditions as recommended by Viveen et al, 1986; for the fry of African catfishes.

5.2.2 Growth performance, mortalities and survival rates of C. nigrodigitatus on live plankton and different levels of dietary crude protein.

The increased weight gain and highest survival rate of C. nigrodigitatus larvae fed on live plankton compared to the poor growth and very high mortalities of larvae fed on artificial diets showed that the larvae were able to ingest, digest and utilize live plankton for growth. Sadykhov et al, (1975); Stephen (1976); Ogino and Watanable (1978); had earlier reported that fish larvae and fry could assimilate 89 to 98% of ingested zooplankton. According to Lannan et al, (1983) that the outstanding qualities of live plankton in terms of size, protein content, palatability, movement, and digestibility are impossible to

match with artificial ration. In this study, all groups of larvae fed on artificial diets resulted in high mortality. There was 100% mortality in groups fed on 35% and 30% crude protein diets after the 5th day of exogenous feeding. There was 98% mortality in group fed on 40% crude protein diet. This result is similar with the works of Van-der Wind 1979, Dabrowski 1978; Krise and Meade 1986; and Bamimore 1989, who reported poor growth and increased mortality when larvae fish were fed on artificial diets. The failure of these formulated/artificial diets could be due to (1) Physical characteristics of the feed such as particle size, texture (Van Limborgh 1979; Tacon and Cowey 1982; Dabrowski and Bardega 1984). (2) Leaching or oxidation of nutrients (Tacon and Cowey 1982). (3) Underdevelopment of digestive system (Stroband and Kroon 1981, Stroband and Dabrowski 1982 in Verreth et al 1987), (4) Apathetic behaviour of larval fish towards the static food particles (Van der Wind 1979). (5) Non-adaptation to a change of diet from zooplankton to artificial feed (Hansen and Borrensen 1989).

However, apart from the nutritional problems associated with high mortality; mortality also occurred as a result of stress of larvae during the normal daily routine of changing the water in the rearing tanks. The culture of C. nigrodigitatus larvae in recirculating water system is strongly recommended, also the use of locally cultured live plankton is also recommended for the feeding of the larval fish, within the range of environmental conditions used in the present study.

5.3.0 Effects of varying dietary protein levels on the growth and nutrient utilization of C. nigrodigitatus

The growth response of C. nigrodigitatus to experimental diets showed that the fish at the three stages of growth viz: fingerlings - juveniles and adults were able to utilize the formulated diets effectively. This confirms the reports of Coche (1982) and Ezenwa (1982) that C. nigrodigitatus readily accepts artificial diets. There were no nutritional diseases or disorder observed morphologically during the experiment, suggesting that the formulated diets used in this study were nutritively

adequate to support growth.

Growth as expressed by the average weight gain, specific growth rate, percentage weight gain (PWG) and the daily rate of growth increased proportionally with increasing protein levels within the range of dietary protein contents used in the present study. This pattern of growth is in agreement with the work of Dahlgren (1979) who reported that increment of dietary protein levels resulted in higher growth rate in channel catfish, Ictalurus punctatus. Similar findings were reported by Nail (1962), Shell (1963) and Tiemeier et al, (1965). The effect of dietary protein on growth rate was also demonstrated in the fingerlings of rainbow trout, Salmo gairdneri as reported by Zeitoun et al, (1973) that increased protein level caused a higher growth rate but reduced survival. However, in this study no mortality of fish was recorded throughout the feeding trial. In general, the growth rate was observed to decrease with increasing size of fish. It was highest in the fingerlings, followed closely were the juveniles and then the adults. This observation is in line with the work of Elliott (1975), Brett (1979) and Jobling

(1983) who indicated that growth rate tends to decrease with size increase. The result of higher growth rate of the male adults than the female adults was because the females utilized more of its nutrient for gonadal growth. Similar observation was reported by Henken et al, (1987) on their studies on growth of males and females of Clarias gariepinus.

5.3.2 Gross protein requirement of C. nigrodigitatus at different stages of growth

Data on growth rate of fish as expressed in terms of weight gain, has been used to define the gross protein requirement of fish and this is actually the minimum amount of dietary protein level to give optimum weight gain (Munson et al, 1954; Phillips et al, 1957; Delong et al 1958; Lovell 1972). On the basis of data collected under the conditions in the present study, it can be established that the optimal (gross) protein requirements for the fingerlings, juveniles, and female adults of C. nigrodigitatus were 35% crude protein and 25% CP for

the male adults. These values are different from those of some workers who reported 40% for the fingerlings of Channel catfish (Dupree and Sneed 196b); 22% for adult of channel catfish (Lovell, 1972); 40% for fingerlings of rainbow trout (N.R.C. 1973); 43% for grass carp fry (Dabrowski 1977); 40% for juvenile mud fish (Faturoti et al. 1986); 40% for Sarotherodon mossambicus juvenile (Jauncey, 1981); and 38% for fingerlings of common carp Cyprinus carpio (Stickney, 1977). The observed differences in the protein requirements of other workers might be due to the methodology in the protein requirement determination, protein components of the diets, level of dietary energy, species differences, environmental conditions and statistical methods. The results are however similar with the work of Mazid et al, (1979) and Arowosoge (1987), who reported 35%CP for the juvenile of Tilapia zillii and Clarias gariepinus respectively. The values are also in line with the recommendations of N.R.C. (1983), that 25 - 30% protein is adequate for large fish, and 30 - 36% protein for fingerlings.

It also agrees with the report of Woynarovich and Horvath (1980) of 35%CP for the matures female fish. The present work has shown that protein requirement is affected by the size and sex of fish. It generally decreases with with increasing size of fish. Thus supporting the works of Thompson 1963; Lovell (1979b) and Milikin (1982). The finding however, contradicts the work of Ayinla (1988); who observed that juveniles of Clarias gariepinus has highest requirement for protein (40%CP) followed by fingerlings with 34%CP and then the fry with requirement of 31%CP.

5.3.3 Effects of experimental diets on the food conversion ratio

The observation that food conversion ratio decreased with increasing dietary protein levels agrees with the work of Jauncey (1982) in Sarotherodon mossambicus, Arowosoge (1987) in Clarias lazera and De-Gani, et al, (1989) in Clarias gariepinus. In the present work, FCR was least in the fingerlings, followed by juveniles, the adult males and highest in the adult females showing that the fingerlings, converted their food more efficiently than the juveniles, and

then the male and female adults. The better feed conversion in the male adult than the females showed that females utilized their nutrients for egg production. Apart from sex, it can be stated that FCR values decrease with increasing size of fish. The reason for this observation, as explained by De-Graaf et al, (1989) is that metabolic processes and energy expenditure per unit body weight decline with increasing body weight or age of fish. This finding agrees with the work of Winfree and Stickney (1981) in Tilapia aurea and Arowosoge (1987), in Clarias gariepinus. It however, contradicts the report of Ayinla (1988) who did not find any relationship between FCR and size of fish. He reported that FCR value is least in the fingerlings followed by the fry and then the juveniles of Clarias gariepinus.

In all the stages of growth examined in this study, it was observed that food conversion was better in fish fed on higher protein diets than those on lower protein diets. This has therefore, shown the supremacy of the higher protein level to give the fish a better food conversion. This observation agrees with the work

of Degani et al, (1989), that food conversion is better in Clarias gariepinus fingerlings fed on a high protein diets (30 - 40%) than those fed on a low protein diet (25 - 30%). Lovell (1979a, 1979b) had earlier reported that fish have the ability to assimilate diets with higher percentages of protein because of their lower energy requirements. As a whole, food conversion ratio was affected by size of fish, sex and dietary protein levels.

On the basis of the results of FCR values obtained in this study, it can be stated that 1.64 kg of 35% crude protein diet will produce 1 kg of fingerlings of C. nigrodigitatus, and 2.57 kg of the same diet will produce 1 kg of juvenile fish. In the adult stage 3.59 kg of 30% crude protein will produce 1 kg of male adults while 5.20 kg of 30%CP will produce 1 kg of the female fish. It must however, be emphasized that better food conversion ratios than those recorded in this study are possible with larger swimming space.

5.3.4 Gross food conversion efficiency

The gross food conversion efficiency obtained in this work ranged from 17.31 to 62.49% in the fingerlings,

9.46 to 39.71% in the juveniles, 7.53 to 28.00% in the male adults. In the juvenile and adult stages, the GFCE values almost fell within the range of 10 - 40% reported by Bret (1971), for sockeye salmon (Oncorhynchus nerka). Reay (1979) reported that values of 15 - 28% of GFCE are common in finfish culture, while Hastings (1976), maintained a range of 0 - 50%. Lasker (1962) reported that gross food conversion efficiency is found in maximum in the utilization of the egg yoke by the embryo. He reported a range of 77 - 79% efficiency in developing pacific pilchard (Sardinops caerules) embryos and sac fry. The general trend in this study was that fingerlings had the highest GFCE value followed by the juveniles, and then the male adults, it was least in the female adults.

5.3.5 Protein efficiency ratio (P.E.R.)

In the fingerlings of C. nigrodigitatus the PER values ranged from 0.86 to 1.78. This range agrees with that of 0.98 to 1.78 obtained for plaice.

(Pleuronectes platessa) fingerlings when fed on varied level of protein diets by Cowey et al, (1974). The juvenile and male adult stages of C. nigrodigitatus had PER values of 0.56 to 1.15 and 0.50 to 1.11 respectively. These values are lower than the values of 2.40 to 4.31 obtained for common carp (Cyprinus carpio) on different dietary protein levels of 7.9 to 53.4% by Ogino and Saito (1970). They are also lower than the range of 1.28 to 2.91 obtained by Jauncey (1982) when juveniles of Sarotherodon mossambicus were fed on 8 - 56% protein diets. Generally, PER was influenced by dietary protein levels, and according to Dabrowski (1979) the effects vary with species and size of fish. In this work, it was found that P.E.R. increased with increasing dietary protein levels. This finding contradicts the work of Ogino and Saito (1970), Dabrowski (1979), in common carp, Jauncey (1981) in Sarotherodon mossambicus juveniles, and Siddiqui et al, (1988) in Oreochromis niloticus fry and fingerlings. These workers reported that PER decreased with increasing dietary protein levels. De-Silva and Perera (1985) did not find a continous decrease in the PER of O. niloticus with increasing dietary protein levels.

However, the finding is in agreement with the work of Arowosoge (1987) in Clarias lazera fingerlings, juveniles and adults. It also agrees with the work of Degani et al, (1989) on the fingerlings of Clarias gariepinus. Generally, the best PER value occurred in the fingerlings, followed by the juveniles, male adults and least in the female adults. As with other parameters PER was affected by different dietary protein levels, size and sex of fish.

5.3.6 Nitrogen metabolism

The result showed that nitrogen metabolism values were higher in fish that were fed on high protein diets than those fed on lower protein levels. Nose (1971) had similar result for rainbow trout, and Dabrowski (1977) for grasscarp (Ctenopharyngodon idella).

5.3.7 Effects of diets on the productive protein value (PPV)

The percentage of protein retained in fish body in relation to the amount consumed was rather low despite the high amount of protein intake. Ayinla (1988) and Falaye (1988); in Clarias gariepinus and "Tilapia" sp. respectively observed low PPV when fish were fed on

different dietary protein levels. Jobling and Wandsink (1983) reported that protein retention value in Arctic Charr is very low and declines as protein content of the diet increases. The possible reasons for the low PPV in C. nigrodigitatus might be that very small amount of the essential amino acids were used for the synthesis of tissue protein, others were probably used for the repairs of worn out cells, enzyme activities, hormones and gonadal development in case of mature fish. The remaining amino acids, because of the nature of the fish to store up fat and because of the efficient mechanism possess by fish generally for protein catabolism and excretion of nitrogen as seen by Smith et al, (1978); were therefore catabolised in a series of steps in which ammonia was eliminated as by-products and the carbonaceous portion of the diet was deposited as fat.

5.3.8 Effects of diets on the body composition

Gross body composition of C. nigrodigitatus in all the three stages of growth and different sexes was affected by experimental diets. It was found that the body protein content was not significantly affected by

dietary protein level but showed a general trend of increase with increasing dietary protein level. This finding is similar to the report of Jauncey (1982) for Sarotherodon (Oreochromis) mossambicus; Papoutsglou and Papaparaskeva- Papoutsoglou (1978) for rainbow trout; Dabrowski (1979) and Zeitler et al (1984) for common carp; Ayinla (1988) and Degani et al (1989) for Clarias gariepinus; De-Silva et al; (1989) and Siddiqui (1988) for Oreochromis niloticus. The percentage of body protein was found to increase with body size. It was lowest in the fingerlings, followed by the juvenile and highest in the adult stages of C. nigrodigitatus, this relationship was however found not to be statistically significant. The finding is similar to those reported by Parker and Vanstone (1966); Denton and Yousef, (1975); and Perera and De-Silva (1978).

It was found that body lipid in C. nigrodigitatus increased with increasing dietary protein level, despite the fact that the experimental diets contained the same amount of fats and other components showing that the dietary protein supply was the only factor governing fat deposition. This report agrees with

the findings of Dębrowski (1977) on grasscarp; and Ayinla (1988) on Clarias gariepinus. However, the result contradicts the work of Ogino et al (1976) in common carp, Luquent and Sabaut (1973), in Gilthead bream; and Cowey et al (1972) in plaice. These workers found that body fat content decrease with increasing protein level of the diet. However, Nose and Arai (1972) did not notice any defined trend in the fat content of eels fed diets containing different levels of protein.

Generally, fish with higher percentage of body lipid are classified as fatty fish, Iles and Woods (1965) and Perera and De-Silva (1978), although the demarcation of fat level as high or low in fish muscle is arbitrary. High percentage of body lipid (7.5 - 17%) permits C. nigrodigitatus to be classified as fatty fish and this range falls within the range of 7.5 to 25% body lipid suggested by Perera and De-Silva (1978) for fatty fish.

The reason for the high body lipid with increasing dietary protein in C. nigrodigitatus might be attributed to the nature of the fish to store up fat, so that amino acids

in the diets in excess of the requirement were deaminated and the non-nitrogenous portion of the protein were deposited as fat. Jobling (1988) had earlier reported that amino acids in excess of requirement in fish were deaminated and used for lipid synthesis. The finding that the percentage of body fat increase as C. nigrodigitatus advanced in size agrees with the reports of Phillips et al (1966); Balbontin et al, (1973); Denton and Yousef (1976); Marais and Erasmus (1977); Papoutsoglou and Papararaskia-Papoustsoghlou (1978); Jobling and Wandsvik (1983); Alexis et al, (1985) and Olaleye (1990), who reported that the most pronounced changes in the body composition of fish as they increase in size/age is increase in the percentage of body fat. The relative high fat deposition in the adult fish may reflects a shift in metabolism towards more fat deposit in preparation for reproduction. This finding further confirms the assertion that adult males and females of C. nigrodigitatus deposited more fat during the process of gonadal growth. The inverse body water and and lipid relationship observed in the present work as seen in other fish species. Brown (1957); Lagler et al(1962);Grayton an

Beamish (1977); Murrary et al; (1977); Dabrowski and Wojno (1977), Jauncey (1980, 1982); and Siddiqui et al, (1988). The observation that the percentage body water content declined as C. nigrodigitatus advanced in size was probably as a result of a rapid increase in body fat content as the fish increased in size. Similar observation had earlier been reported by Denton and Yousef (1975); Perera and De-Silva (1978), in the body of grey mullet (Mugil cephalus), Jobling and Wandsvak (1983); in the body of Arctic Charr (Salvelinus alpinus). Body ash content in C. nigrodigitatus was unaffected by dietary protein levels and different sizes of fish. This agrees with the work of Yu et al; (1977).

It was noted, that body carbohydrate was very small in all the stages of growth examined, showing that C. nigrodigitatus did not store up carbohydrate, and that a major portion of the carbohydrate in the diet was utilized for energy purposes, excess deposited as fat. The fraction that was estimated was probably derived from structural sources such as glycoproteins, and glycolipids as observed in the young mullet (Perera and De-Silva (1978).

Overall, the body composition of C. nigrodigitatus was affected by dietary protein levels, fish size, sex and growth of fish. All fish with poor growth showed a lower body lipid content and a higher body moisture and ash content than those with good growth.

Chapter 6

Conclusion and recommendations

This study has shown that females of Chrysichthys nigrodigitatus had an annual reproductive cycle of four distinct phases. The gonadal preparatory phase occurred between September and December. The prespawning phase or maturing phase was between January and February. The spawning stage was in March and April. The resting stage occurred during the months of June to August. In the males, two distinct reproductive phases were indicated; these were the growth phase which occurred between July and February and the spawning phase which occurred between March and May. The peak prespawning and spawning periods coincided with period of dry season when there was low rainfall and low food supply and when fish were probably feeding low. In order to maximize reproductive potential, C. nigrodigitatus developed a reproductive strategy of low fecundity, large yolky eggs which were uniform in size and storage of lipids in the muscle and liver during the initial periods of gonadal growth. The lipids were utilized for final maturation of the gonads, spawning activities and parental care. The pattern of utilization, however,

differed between sexes. The females withdrew lipids mainly from their bodies for ovarian maturation while the males withdrew lipids from their livers for testicular maturation. Immediately after spawning lipids were withdrawn from the liver of the female fish for parental care and other activities. The results of energy reservation, its mobilization and utilization followed the same pattern with those of the lipids. There was a considerable drain of energy due to gonadal maturation in both sexes and it was higher in the female. The protein levels of the muscle and liver in both sexes remained fairly constant during the different stages of gonadal development, indicating that the range of fat levels in C. nigrodigitatus were dependent on the gonadal state of the fish, while the protein levels were independent of the gonadal stages. The study has also revealed that C. nigrodigitatus had regulatory mechanism to transfer energy/lipid from the soma or liver to the gonads. This regulation of energy partitioning ensured that the gonads were ripe when the environmental conditions were favourable even in the face of low food supply.

Observed environmental features coinciding with spawning in sexually mature individuals in Asejire lake included low water level, presence of suitable spawning substrate, direct contact with mature partner and a gentle flow of water across the spawning substrate. There was derangement of reproduction when sexually mature fish were transferred from their natural environment to concrete tanks. This simple method applied in this study to induce spawning in C. nigrodigitatus is recommended to fish farmers. As this method is easy, non-expensive and allows for the mass rearing of the eggs and larvae in a well protected environment.

The observed morphological and behavioural pattern of developments in the larval fish will eliminate ill-timed handling and late or inappropriate food introduction by fish culturist. The techniques recommended for the rearing of larvae of C. nigrodigitatus are continous supply of air and water to the culture medium. Feeding with live plankton and to provide the first feeding before the final utilization of yolk. The recorded range of the water quality in the culture medium may have to be maintained for a successful use of the live plankton

as the first food for the larval of C. nigrodigitatus. In order to reduce mortality resulting from stress of larvae during the normal routine of changing culture water, a recirculating water system is strongly recommended.

The effects of different dietary protein levels on the growth and nutrient utilization of fish showed that the fingerlings, juvenile and adults of both sexes of C. nigrodigitatus could be reared successfully on artificial diets. Fingerlings and juvenile fed on 35% crude protein had the fastest growth rate and best nutrient utilization. Male and female adults thrived best on 25% and 35% crude protein diets respectively. This finding has therefore suggested that practical catfish diets containing 35% crude protein can now be developed and used as a starter feed for the fingerlings and juvenile fish and can also be used as breeder's feed for the female adults. A 25% crude protein diet can be developed for the male adults. The results of carcass analysis revealed that C. nigrodigitatus was a fatty fish.

Finally, the results of the present study have made available information on the reproductive cycle

of C. nigrodigitatus and this can be used for the effective management of the species within its natural habitat. The results of its nutrient cycling during gonadal development have now thrown light to where the nutrients especially lipids are reserved, mobilized and utilized during different stages of gonadal development. This can assist the fish farmers on when to intensify feeding during the period of gonadal development.

REFERENCES

Aboaba, M.A. (1984). Effect of different nutrient sources on the performance and serum protein components of Tilapia nilotica (Oreochromics niloticus). M.Sc Thesis, University of Ibadan, Ibadan, Nigeria.

Ackman, R.G. Eaton, C.A. and Hingley, J. (1969) In love, R.M.(1983). The chemical biology of fishes. Vol. 2. Academic press. London, New York.

Afinnowi, M.A. and Morioghae, I. (1986). Summary of Aquaculture activities in Nigeria. In Research Priorities for African Aquaculture. Report for a workshop held in Dakar , Senegal, October, 13-16, 1986. IDRC - MR149e.

Ajayi, O. (1972). Biological studies on the family Bagridae (Pisces siluroidae) in Lake Kainji, Nigeria. M. Phill. Thesis, University of Ife, Ile-Ife, Nigeria.

AL- Daham, N.K. and Bhatti M.N. (1970). Annual changes in the ovarian activity of the freshwater teleost, Barbus luteus (Heckel) from Southern Iraq. J. Fish Biol. 14. 381-387.

Alexis, M.N. Papaparaskeva - Papoutsoglou, E. and Theochari, V. (1985). Formulation of practical diets for rainbow trout (Salmo gairdner:) made by partial or complete substitution of fish meal by poultry by - products and certain plant by - products. Aquaculture, 50: 61-73.

Andrews, J.W., Knight, L.H. Page, J.W. Matsuda, Y. and Brown, E.E. (1970). The interaction of stocking density and water turnover on growth and feed conversion of channel catfish reared in intensively stocked tanks. The Progressive Fish-Culturist, 33:(4) 197-203.

Andrews, J.W., Murai, T. and Gibbons, G. (1971). The influence of dissolved oxygen on growth of channel catfish. Transactions of the American Fisheries Society, Washington.

Andrews, J.W. and Stickney, R.R. (1982), Interactions of feeding rates and environmental remperature on growth, food conversion and body composition of channel catfish. Transaction of the American Fisheries Society, Bethesda, 101(1): 94-97.

A.O.A.C. (1980). Official methods of Analysis (edited by Horwitz). 13th edition, Association of official Analytical Chemists: Washington D.C.

Applegate, R.L. (1981). Food selection of Musken Uunge Fry. Prog. Fish-cult. 43(3), 136-139.

Apstein, C. (1909) cited in Coombs, S.H. and Biby A.R. (1979). The development of the eggs and early larvae of blue whiting, Micromesistius poutassou and the effect of temperatue on the development. J. Fish Biol. 14, 111-123.

Arnemo, R; Puke , C., Steffner, N.G. (1980). Feeding during the first weeks of young salmon in a pond. Arch. Hydrobiol 89(1½): 265-273.

Arowosoge, I.A. (1987). Nutritional implications of cottonseed meal in the diets of clarias lazera (C & V). Ph.D. Thesis, Univ. of Ibadan, Ibadan, Nigeria.

Attack, T.H. Jauncey, K. and Matty, A.J. (1979). The utilization of some single cell proteins by finger lings common carp (Cyprinus carpio) Aquaculture 18: 337-348.

Ayinla, O.A. (1988). Nutrition and reproductive performance of Clarcias gariepinus. Ph.D Thesis, University of Ibadan, Ibadan, Nigeria.

Austreng, E. Risa, S. Edwards, D.J. and Huidsten, H. (1977). Carbohydrate in rainbow trout diets. II. Influence of carbohydrate levels on chemical composition and feed utilization of fish from different families. Aquaculture, Amsterdam, II: 39-50.

Babikar, M.M. and Ibrahim, H. (1979). Studies on the biology of reproduction in the Cichlid Tilapia nilotica (L): gonadal maturation and fecundity. J. Fish Biol. 14: 437-448.

Bagenal, T.B. (1969). The relationship between food supply and fecundity in Brown trout Salmon trutta (L). J. Fish Biol. 1, 167-182.

Balbontin, F., Desilua, S.S and Ehrlich, K.F. (1973) A comparative study of anatomical and chemical characteristics of reared and wild herrong. Aquaculture. 2: 217-240.

Bamimore, M.A. (1989). Performance of African catfish fry (Clarias gariepinus) raised on natural and artificial diets in a hatchery. M.Phil Thesis Univ. of Ibadan, Nigeria.

Bardach, J.E. Ryther, J.H. and Mclarney, W.D. (1972), Aquaculture: The farming and husbandary of freshwater and marine organisms. Wiley Inter-sciences. New York.

Bell, F.W. (1975). Food from the sea. The economics and politics of ocean fisheries. Westview Press, Boulder, Colorado.

Benzie, V.L. (1968). The life history of Galaxias vulgaris stokell with a comparison with G. maculatus attennuatus No. 2. J. Mar. Freshwater Res. 2, 628-653.

Bergot, F. (1979). Carbohydrate in trout diets. Effects of the level and source of carbohydrate and the number of meals on growth and body composition. Aquaculture, 18: 157-167.

Beyerle, G.B. (1979). In Krise, W.F: and Meade, J.W. (1986). Review of the intensive culture of walleye fry. The progressive Fish-cult. 48(2) 81-89.

Blaxter J.H.S. (1962). Herring rearing IV. Rearing beyond the yolk sac stage. Marine research 1. 18 p.

Blaxter, J.H.S. (1969). Development: Eggs and larvae. In Fish Physiology (W.S. Hoar and D.J. Randall eds), Vol. III. 177-252. New York Academic press.

Bogoyaulenskaya, M.P., and Veltishcheva, I.F. (1972). Some data on age changes in the fat and carbohydrate metabolism in Baltic sea cod. J. Fish Res. Board Can. Transl. Ser. No. 2730, 1973.

Bogoyaulenskaya, M.P. and Veltishcheua, I.F. (1972). In Love, R.M. (1983). The chemical biology of fishes. Vol. 2. Academic press, Lodon, New York.

Bond, C. (1979). Feeding and nutrition in Biology of fishes. 391-404.

Bone, Q. and Marshall, N.B. (1986). Biology of fishes. Tertiary level biology Blackie. Glasgow and London 253 p.

Brett, J.R. (1971). Satiation time, appetite, and maximum food intake of sockeye salmon (Oncorhynchus nerka). Journal of the fisheries research Board of Canada Ottawa, 28: 409-415.

Brett, J.R. (1976) Scope from metabolism and growth of sockeye salmon, Oncorhynchus nerka and some related energetics. J. Fish. Res. Bd. Can. 33: 307-313.

Brett, J.R. (1979). Environmental factors and growth. In: Hoar, W.S. and Randall, D.J. and Brett, J.R. (eds). Fish Physiology, Vol VIII, 278-352. New York, Academic Press.

Britz, P.J. and Hecht, T. (1987). Temperature preference and optimum temperature growth of African sharptooth catfish (Clarias gariepinus) larvae and post larvae. Aquaculture 63: 233-241.

Brown, M.E. (1957). Experimental studies on growth. Physiology of fishes Vol. 1. 361-400. Academic press Inc. New York.

Bruton, M.N. (1979). In Stancey, N.E. (1985). Fish reproduction. Academic press Inc. London.

Cadwallader P.L.(1976). Breeding biology of a non-diadromous galaxiid, Galaxias vulgaris stokell, in a New Zealand river. J. Fish Biol. 8: 157 - 177).

Chakrabarty, R.B., Sen, P.R., Chatterjee D.K. and Kowtal, G.V. (1973). Observations on the relative usefulness of different feed for carp spawn and fry. In Principles and practices of pond aquaculture. Edited by J.E. Lannan, R.O. Smitherman and G. Tchobanaglous. (1982). Oregon press state University press. Corvallis, Oregan.

Chakroff, M. (1976). Freshwater fish cultures and management. VITA Publications manual series number 36E.

Campbell, S. and Love, R.M. (1978). Energy reserves of male and female haddock (Melanogrammus aeglefinus L.) from the Moray Firth. J. Cons. Int. Explor. mer 38: 120 - 121.

Chan, E.H., and T.E. Chua (1979). The food and feeding habits of greenback grey mullet, Liza subvirdis (Valencienners), from different habitats and at various stages of growth. J. Fish. Biol. 15: 165-171.

Chan, E.H. and Chua, T.E. (1980). Reproduction in the greenback grey mullet. Liza subviridis (Valenciennes, 1836). J. Fish Biol. 16: 505-519pp.

Chen, L.C. and Martinich, R.U. (1975). Pheromonal Stimulation and metabolite inhibition of ovulation in zebrafish, Brachydanio revio. Fish. Bull. 73: 889-894.

Chepurnou, A.V. and Tkachenko, N.K. (1973). Charges in the lipid composition of females and males of the Black sea round goby (Neogobius melanostomus) in the spawning period and in early ontogenesis. In: Love, R.M. (1983). Chemical biology of fishes. Vol. 2. Academic press. London. New York, Toronto. Sydney. San-Francisco.

Chow, K.W. (1981). Micro-encapsulated egg diets for fish larvae. F.A.O. Rome, Italy. ADCP/REP/80/11.

Chow, K.W. and Schell, W.R. (1980). The minerals. In Fish Technology. UNDP/FAO, ADCP/Rep/80/11, 104 - 108p.

Ciechomski, J. Dz. (1966). Development of the larvae and variations in the size of the eggs of the Argentine anchovy, Engraulis anchoita Buhhs and Marini J. du. Cons. 30, 281-290.

Coche, A.G. (1982): On the economics of the production of the catfish Cnrysichthys nigrodigitatus in brackish water ponds in Nigeria. Coastal aquaculture: Development perspectives in Africa and case studies from other regions. CIFA TECH. PAP/DOC. TECH. CPCA, No. 9, 81-99pp.

Combs, G.F. and Nicholsen , F.C. (1962). In Halver, J.E. (1972). Fish nutrition Academic press, London. 327-371p.

Cowey C.B. (1976). The use of synthetic diets and biochemical criteria in the assessment of fish. J. Fish. Res. Bd Canada 33: 4(2) 1040-1045p.

Cowey, C.B. and Sargent, J.R. (1972). Fish Nutrition. Advances in Marine Biology. London/New York. 10: 383-492.

Cowey, C.B., Pope, J.A., Adron, J.W. and Blair, A. (1972). Studies on the nutrition of marine flat-fish. The protein requirement of plaice, Pleuronectes platessa. British Journal of Nutrition, 28: 447-456.

Cowey, C.B. , Adron, J.W., Brown, D.A. and Shanks, A.N. (1974). Studies on the nutrition fo marine flatfish. Utilization of various dietary protein by plaice (Pleuronectes platessa). British Journal of Nutrition. 31(3): 297-306.

Cowey, C.B., Adron, J.W., Brow, D.A. and Shanks, A.M. (1975). Studies on the nutrition of marine flatfish. The metabolism of glucuse by plaice (Pleuronectes platessa) and the effects of dietary energy source on protein utilization in plaice. Br. J. Nutr., 33: 219-231.

Craig, J.F. (1977). The body composition of adult perch, Perca fluviatilis in windermere, with reference to seasonal charges and reproduction. J. Anim. Ecol. 46. 617-632.

Cruz. E.M. and Lardencia, L.L. (1977). Protein requirements of Tilapia mossambica fingerlings. Kali kasar Phillip. J. Biol 6: 177-182.

Cuff. W.R. (1977). Iniatiation and control of cannibalism in larval walleyes. Prog. Fish-cult. 39: 29-32.

Cuff W.R. (1980). Behavioural aspects of cannibalism in larval walleye. Vitreum vitreum. Canadian Journal of Zoology 58: 1504-1507.

Dabrowski, K. (1977). Protein requirements of grass carp fry (Ctenopharyngodon idella). Aquaculture, 12: 63-73.

Dabrowski, K. (1979). Feeding requirements of fish with particular attention to common carp. A review. Arch Hydrobiol. 26: 112, 135-158p.

Dabrowski, K. and Wojno, T. (1977). Studies on the utilization by rainbow trout (Salmo garidneri) of feed mixtures containing soyabean meal and an addition of amino acids. Aquaculture. 10: 297-310p.

Dabrowski, K. and Dabrowiska, H. (1981). Digestion of protein by rainbow trout (Salmo gairdneri) and absorption of amino acids within the alimentary tracts. Comp. Biochem. Physiol., 69A: 99-111p.

Dabrowski, K. Dabrowska, H. and Grudiewski, C. (1978). A study of the feeding of common carp larvae with artificial food. Aquaculture 13: 257-264.

Delahunty, G. and De Vlaming, V.L. (1980). Seasonal relationships of ovary weight, liver weight and fat stores with body weight in the goldfish. Carassius auratus L. J. Fish Biol. 16: 5-13.

Delong, D.C. Halver, J.E. and Mertz, E.T. (1958). Nutrition of Salmonid fishes VI. Protein reguirements of Chinook salmon at two water temperatures. J. Nutr. 65: 589-599.

Denton, J.E. and Yousef, M.K..(1976). Body composition and organ wights of rainbow trout. Salmo gairdneri. J. Fish. Biol: 8: 489-499.

De-Silva, S.S. (1973). Aspects of the reproductive biology of the sprat, Sprattus sprattus (L.) in inshore waters of the west coast of Scotland J. Fish Biol, 5 689-705

De-Silva, S.S. and Perera, W.M.E. (1985). Effect of dietary protein level on growth, food conversion and protein use in young Tilapia nilotica at four salinities. Trans. Am. Fish. Soc., 114: 584-589.

Dodd J.M. (1977). The structure of the ovary of non-mammalian vertebrates. In: The ovary. 2nd edn, (S. Zuckerman and B.J. Weir, eds.) Vol. 11. 219-263p. London: Academic Press Inc.

Dupree, H.K. (1966). Vitamins essential for growth of channel catfish. Tech. Pap. Bur. Sport. Fish Wild USFWS 7: 22-25p.

Dupree, H.K. (1969). Influence of corn oil and beef tallow on growth of channel catfish. Bur. Sport Fish wildc. Tech. Paper, No. 27, 13-16p.

Dupree, H.K. (1976). Some practical feeding and management teachniques for fish farmers. Proceedings of the 1976 Fish Farming Conference and Annual Convention of Catfish farmers of Texas 77-83p.

Dupree, H.K, and Huner, J.V. (1984). Third report to the fish farmers. The status of warmwater fish farming and progress in Fish farming research. H.K. Dupree and J.V. Huner (eds). U.S. Fish and wildlife service Washington, D.C. 270p.

Dupree, H.K. and Sneed, K.E. (1966). Response of Channel catfish fingerlings to different levels of major nutrients in purified diets. Tech. Pap. Bur. Sprt. Fish Wild. USFWS

Eaton, R.C. and Farley, R.D. (1974). Growth and reduction of dispensation of zebrafish, Brachydanio rerio, reared in the laboratory. Cited by Paul W.W. (1978). Ecology of Fresh water fish production. Gerking S.D(ed). Blackwell sceintific publications Oxford, London, Edinburgh, Melbourne.

Ehrlich, K.F. (1972): In Ehrlich, K.F. (1974): Chemical changes during growth and starvation of larval Pleuronectes platessa. Mar. Biol. 24: 33-48.

Ehrlich, K.F. (1974). Chemical changes during growth and starvation of larval Pleuronectes platessa Mar. Biol. 24; 33-38.

Elliot, O.O. (1975). Biological observations of some specie used for aquaculture in Nigeria. FAO/CIFA symposium on aquaculture in Africa, Accra, Ghana, CIFA/75 1 SE 8).

Elliot, J.M. (1975a). Number of meals in a day and maximum weight of food consumed in a day and maximum rate of feeding for brown trout, Salmo trutta L. Freshwater Biology Oxford, S: 287-303.

Elliot, J.M. (1975b). The growth of brown trout (Salmo trutta (L.) fed on reduced rations. Journal of Animal Ecology, 44: 823-824.

Erland (1979) cited in L.L.U. Ugwu (1984). Protein requirement of Clarias fry. M.Sc. Thesis, Univ. of Ibadan.

Ezenwa, B.I.O. (1976). Fish seed production in Nigeria. In symposium on Aquaculture in Africa, Accra, Ghana 30th September - 2nd October 1975 CIFA Tech. Pap (4) Suppl. 1: 441-449p.

Ezenwa, B.I.O. (1978). Studies on the distribution, age and growth of the catfish, Chrysichthys nigrodigitatus. M.Sc. Thesis, Univ. of Lagos, Lagos, Nigeria.

Ezenwa, B.I.O. (1981). A study of the reproductive biology of the catfish Chrysichthys nigrodigitatus (Lacepede) in Nigeria. Ph.D. Thesis, Univ. Of Lagos, Lagos, Nigeria.

Ezenwa, B.I.O. (1982). Production of Catfish Chrysichthys nigrodigitatus, in Nigeria using groundnut cake as supplemental feed. Aquaculture 27(3): 197-203.

Fabian, M.W. (1960). Mortality of fresh water and tropical fish fry by cyclopoid copepods. Citation in Hokanson, K.E.F. and Lien G. (1986) on effects of diet on growth and survival of larval walleyes. The Progressive Fish-culturist 48: 250-258.

Falaye, A.E. (1988). Utilization of cocoa husk in the nutrition of "Tilapia" (Oreochromis niloticus Trewavas) Ph.D. Thesis. University of Ibadan, Ibadan, Nigeria.

Fagade, S.O. and Olaniyan C.I.O. (1973). The food and feeding interrelationaship of fishes in the Lagos lagoon. J. Fish Biol., 5: 205-225.

Fagade, S.O. and Adebisi, A.A. (1979). On the fecundity of Chrysichthys nigrodigitatus (Lacepede) of Asejire dam, Oyo State, Nigerian. Nig. J. Nat. Sci. 1(2):127-131.

F.A.O. (1966). Agricultural Development in Nigeria 1965-1980. Willams Clowes and Sons Ltd. London and Beccles.

F.A.O. (1975). The production of fishmeal and oil. FAO Fish. Tech. Pap. No. 142. 54p.

F.A.O. (1986). Nutrition and Fisheries. Food and Nutrition Vol. 12: 2. 64pp.

F.D.F. (1988). Federal Department of fisheries, Lagos, 1988 annual report.

F.D.F. (1990). Federal Department of Fisheries, Lagos. Fisheries statistic of Nigeri, 1990 Annual report.

Fetuga, B.L. (1975). Assessment of protein quality of certain Nigeria foods and feedstuff in the Nutrition of pigs and rats. Ph.D. Thesis, Univ. of Ibadan, Ibadan, Nigeria.

Faturoti, E.O. Balogun, A.M. and Ugwu, L.L.C. (1986). Nutrient utilization and growth responses of Clarias uzera fed different dietary protein levels. Nigerian J. App. Fish. and Hydrobiol., 1: 41-45.

Forrester, C.R. and Alderdice, D.F. (1966). Effects of salinity and temperature on embryonic development of the pacific cod (Gadus macrocephalus). J. Fisheries. Res. Board. Can. 23, 319-34op.

Fowler, L.G. McCormick, J.H.Jr. and Thomas A.E. (1964). Further studies of protein and calorie levels of meat-meal, vitamin suplemented salmon diets. U.S. Fish Wildl. Ser. Spec. Sci. Rep. Fish, 480: 13-16.

Fryer, G. (1959): The trophic interrelaship and ecology of some littoral communities of lake Nyasa with special reference to the fishes and a discussion of rock-frequenting cichlidae Proc. Zool. Soc. Lond., 132: 152-281.

Fryer, G. and Iles, T.D. (1972). The Cichlid fishes of the Great lakes. Their Biology and Evolution - Oliver and Boyd; Edinburgh. 641pp.

Gannon, J.E. (1976). The effects of differential digestion rates of zooplankton by Alewife, Alosa pseudopharengus on determinations of selective feedings. Trans. Am. Fish. Soc. 105: 89-95.

Gardling, D.L. Jr. and Wilson, R.P. (1976). Optimum dietar protein to energy ratio for channel catfish fingerlings Lctalurus punctatus. J. Nutr., 106: 1368-1375.

Gerkings S.D. (1955a). Influences of rate of feeding on composition and protein metabolism of blue gill sunfish. Physiol. Zool., 28: 267-282.

Gohl, B.O. (1985). Tropical feeds. F.AO. Rome (2nd edition

Gorbunova, N.N. and N.Y. Lipskaya. (1975). Feeding of larvae of blue marlin, Makaira nugricans cited in Principles and practices of pond aquaculture. J.E. Lannan R.O. Smitherman and Tchobanoglous edition. Oregon State University Press, Oregon.

Grayton, B.D. and F.W. Beamish (1977). Effects of feeding frequency on food intake, growth and body composition of rainbow trout. (Salmo gairdneri), Aquaculture, 11: 159-172.

Gupta, S. (1974). Observation on the reproductive biology of Mastacembelus armatus (Lacepede). J. Fish. Biol. 6: 13-21.

Hails, A.J. (1983). Temporal changes in fat and protein levels in the tropical Anabantid Trichogaster pectoralis (Regan). J. Fish. Biol. 22: 203-213.

Halver, J.E. (1957). Nutrition of Salmonid fishes. IV. An amino acid test for Chinook salmon. J. Nutr. 62: 245-254.

Halver, J.E. (1979). Vitamin requirements of foifish. In J.E. Halver and K. Tiews (eds), Finfish Nutrition and Fishfeed Technology H. Heenemann GmbH and Co. Berlin Vol. I.

Hansen, P.E., Lied, E. and Borrensen, T. (1989). Estimation of protein synthesis in fish larvae using an in vitro Polyribosome assay. Aquaculture, 79(1-4): 85-89p.

Hastings, W.H. (1976). Fish nutrition and fish feed manufacture in: Advances on Aquaculture. T.V.R. Pillay and W.A. Dill (eds). Farnharn England. Fishing News book. 506-569.

Heltter, O. (1981). Spawning and rearing of Atlantic Menhaden Prog. Fish - Cult. 43 (3) (17 - 120p.

Hem. S. (1982). L' aquaculture en englos: Adaptation au milieu lagunaire Ivoirein. Aquaculture, 27(3), 261-272.

Hem. S. (1985). Premiers resultats sur la reproduction controllee de Chrysichthy nigrodigitatus en milieu d'elvage. Cikkigye FIS, Aquaculture en Afrique, du 7 au 11 Octobre 1985, Kisumu IKenya 19pp.

Henken, A.M., Boon J.B., Cattel, B.C., and H.W.J. Lobee (1987). Differences in growth rate and feed utilization between male and female African catfish, Clarias gariepinus (Burcheu) Aquaculture, 63: 221-232.

Hepher, B. (1975). Supplementary feeding in fish culture. Citation in principles and practices of pond aquaculture. J.E. Lannan R.O. Smitherman and G. Tchoban glous (eds) Oregon State University Press.

Hirano, R. (1969). Rearing of black sea bream larva. cited in Lee C., Hu, F. and Hirano, R. (1981). Prog. Fish-cult 43(3), 121-123p.

Hogendoorn, H., Jansen, J.A.J., Kroops, W.J. Machiels, M.A.M., Van Ewijk, P.H. and Van Hees J.P. (1983). Growth and production of the African catfish, Clarias lazera (C & V). II. Effects of body weight temperature and feeding level in intensive tank culture. Aquaculture, 34: 265-285.

Holden , M. and Reed, W. (1972). Fish and Fisheries of Northern Nigeria. Ministry of Agric. Zaria; Gaskiya printers.

Htun - Han, M. (1978). The reproductive biology of the Limanda limanda (L,) in the North sea. gonosomatic index, hepatosomatic index and condition factor. J. Fish Biol. 13: 309-378.

Ibrahim, K.H. (1985). Aquaculture research in Africa. In Village level Aquaculture development in Africa. H.R. King and K.H.Ibrahim(eds.) Commonwealth Secretariat 109-120.

Ikusemiju, K. (1976). Distribution, reproduction and growth of the catfish, Chrysichthys walkeri (Gunther) in the Lekki Lagoon, Nigeria. J. Fish. Biol. 8: 453-458.

Ikusemiju, K. and Olaniyan, C.I.O. (1977). The food and feeding habits of catfish Chrysicthys walkeri, Chrysichthys filamentosus and Chrysichthys nigrodigitatus in Lekki Lagoon. J. Fish Biol. 10: 105-112.

Iles, T.D. (1974). The tactics and strategy of growth in fishes. In Sea Fisheries Research (J.R. Harden Jones, ed.) 331-345, London: Flek.

Iles, T. D. and Woods, R.J. (1965). The fat/water relationship of North sea herring Clupea harengus and its possible significance. J. Mar. Biol. Ass. U.K. 45: 353-366.

Imevbore, A.M.A. (1970). "Some preliminary observation on the sex ratio and fecundity of the fish in River Niger" In Kainji - a Nigerian man-made lake. Vol. 1 (ed. Visser, S.A) NISER: Ibadan. 87-98.

Jackson, A.J. Capper, B.S. and Matty, A.J. (1982). Evaluation of some plant proteins in a complete diet for the tilapia, Sarotherodan mossambicus. Aquaculture. 27: 7-109.

Jauncey, K. (1980). The effects of varying deitary composition on carp (Cyprinus carpio) maintained in thermal effluents and laboratory recycling systems. Proc. World. Symp. on Aquaculture in heated effluents and recirculation systems Stavenger 28-30 May, 1980. Vol. II, Berlin, 249-261pp.

Jauncey, K. (1981). The effects of varying dietary protein levels on growth, food conversion, protein utilization and body composition of juvenile tilapias (Sarotherodon mossambicus) Aquaculture, 18: 115-122.

Jauncey, K. (1982). The effects of varying protein level on growth, food conversion, protein utilization of tilapia, Sarotherodon mossambicus. Aquaculture 27: 43-54.

Jobling, M. (1983). A short review and critique of methodology used in fish growth and nutrition studies J. Fish. Biol: 23: 685-703.

Jobling, M. (1988). A review of the Physiological and nutritional energetics of cod, Gadus morhua (L.) with particular reference to growth under farmed conditions. Aquaculture 70: 1-19.

Jobling, M. and Wardsivik, A. (1983). Effect of social interaction on growth rates and conversion efficiency of Artic charr. Salvelinus alpinus J. Fish. Biol. 22: 577-584.

Jones, A. (1970). Some aspects of the biology of turbot (Scophthalmus) maximus (L) In Htun-han, M. (1978). The Reproductive biology of the dab. (Limanda limanda) in the North sea: gonosomatic index, hepatosomatic index and condition factor.

Ke, P.J., Power, H.E. and Regier, L.W. (1969). In Love, R.M. (1983) Chemical biology of fishes. Academic press. London. New York.

Kennedy, M. (1969). Spawning and early development of the dace Leuciscus leuciscus. J. Fish Biol. 1: 249-259.

Kenneth, E.F. Hokanson and G. Lien (1986). Effects of diet on growth and survival of larval walleyes. The Progressive Fish-cultrist 48: 250-258.

Kim, K.I., Hayes T.B. and Amundsen, C.H. (1983). Protein and arginine requirement of rainbow trout. Fed. Proc. 42: 2198 (Abstract).

Klein, R.G. and Halver, J.E. (1970). Nutrition of Salmonid fishes: arginine and histidine requirement of Chinook and Coho Salmon. J. Nutr. 100. 1105.

Kramer, D.L. (1972). Animal Behaviour. 20: 789-807.

Krise, W.F. and Meade, J.W. (1982). In Krise, W.F. and Meade, J.W. (1986). Review of the intensive culture of the walleye fry. The progressive fish - culturist 48: 81-89.

Krise, W.F. and Meade, J.W. (1986). Review of the intensive culture of walleye fry. The progressive fish - culturist. 48. 81-89.

Krivobok, M.N. (1964). On the role of the liver in the maturation of the ovaries of the Baltic herring, Clupea hareigus membras (L). in Htun-han, M. (1978). The reproductive biology of the dab Limanda limanda (L) in the North sea: gonosomatic index, hepatosomatic index and condition factor J. Fish Biol. 13: 369-378.

Kuo, C.M., Shehadeh, Z.H. and M. Lisen K.K. (1973). A preliminary report on the development, growth and survival of laboratory-reared larvae of the grey mullet (Mugil cephalus L.) J. Fish. Biol. 5 459-470.

Lagler, K.F., Bardach, J.E. and Miller, R.R. (1962). Ichthyology. The study of fishes, New York; John Wiley and Sons Inc. 280-285.

Lagler, K.F., Bardach, J.E., Miller, R.R. Passion, D.M. (1979) Ichthyology (2nd edn.). John Wiley and Sons, New York. 1-506pp.

Lall, S.P. (1979). Minerals in finfish nutrition pp. 85-97. In J.E. Halver and K. Tiews (eds), Finfish Nutrition and Fishfeed Technology H. Heenemann Gmb4 and Co., Berlin. Vol. 1.

Lannan, J.E., Smitherman, R.O. and Tchobanglous G. (1983). Principles and practices of pond aquaculture. Oregon State University Press Corvallis, Oregon.

Larson, G.L. (1974). Liver weight of brook trout in a high-mountain lake in Washington State. Progve. Fish Cult. 35: 234-236.

Lasker, R. (1962). Efficiency and rate of yolk utilization by developing embryos and larvae of pacific sardine (Sardinops carulea Girord) J. Fish Res. Bd. Can. 19(5): 867-875.

Lasker, R. (1970). Utilization of zooplankton energy by a Pacific sardine population in the California current. In: Steele, J.H. (ed.) Marine Food Chains, 265-284p. Edinburgh Oliver and Boyd.

Lasker, R. (1974). In "Proceedings of the fifth Annual meeting, world mariculture society" Louisiana State University, Baton Rouge, Louisiana. 313-318pp.

Lasker, R. (1975). Field criteria for survival of anchovy larvae. Fishery Bulletin 73(3): 453 - 462pp.

Le Cren E.D.(1951) . The length-weight relationship and seasonal cycle in gonad weight and condition in perch (Perca fluviatilis) J. Anim. Ecol. 20: 201-219.

Lee, C.K.C. (1972). The biology and population dynamics of the common dab Limonda Liwandi (L) in the North Sea. Ph.D Thesi Univ. of East Anglia, U.K. 105pp.

Lee, D.J. and Putnam, G.B. (1973). The response of rainbow trout to varying protein/energy ratios in a test diet. J. Nutr. 103: 916-922.

Li, S., and Mathias, J.A. (1982). Causes of high mortality among cultured larval avalleyes. Trans. Am. Fish Soc. 111: 710-721.

Liao, I.C.,. Lu, U.J. Huang, T.L. and Lin M.C. (1971). Expe riments on induced breeding of grey mullet, Mugil cephalus Linnaeus. In C.M. Kuo 2. H Shehadeh and K.K. Milisen (1973). J. Fish Biol. 5 459-470.

Liley, R.N. (1980). In "Fish Behaviour and its role in the capture and culture of fish" (J.E. Bardach, J.J. Magnuson, R.C. May and J.M. Reinhart, eds). ICLARM Conference Proceedings 5, Manila. 210-246p

Liley, R.N. (1982). Chemical communication in fish. Can. J. Fish. Aquat. Sci. 39: 111-137.

Love, R.M. (1970). The chemical biology of fishes. London and New York Academic Press.

Love, R.M. (1976). Processing cod: the influence of season and fishing ground. In Love R.M. 1983. Chemical biology of fishes. Academic Press, London.

Love, R.M. (1978). Dark colour in white fish flesh. In love R.M. (1983). Chemical biology of fishes Academic press. London New York.

Love, R.M. (1983). The chemical biology of fishes. Academic press. London New York, Toronto, Sydney San Francisco. 443p.

Lovell, R.T. (1972). Protein requirements of cage-cultured channel catfish Proc. S.E. Assoc. Game Fish. Coma 26: 357-361.

Lovell, R.T. (1977). Mineral requirements. In R.R. Stickney and R.T. Lovell (eds). Nutrition and feeding of Channel catfish. Southern Cooperative Series Bulletin, 218: 30-32.

Lovell, R.T. (1979a). Formulating diets for aquaculture species. Feedstuffs 51(27): 29, 32 (July 9).

Lovell, R.T. (1979b). Fish culture in the United States. Science 206: 1368-1372.

Luquent, P., and J.J. Sabau (1973). Preliminary study on the protein requirements of the gilthead bream, (Chrisophorys aurata). Stud. Rev. GFCM 52: 80-90.

Marais, J.F.K. and Erasmus, T. (1977). Body composition of mugil cephalus and Liza tricuspidens (Teleostei: mugilidae) caught in the Swartkops estuary. Aquaculture, London 10: 75-86.

Marr. J.C. (1956). The critical period in the early life history of marine fishes. Cited by Braum E. (1978) Ecology of freshwater fish production. Gerking ed. Blackwell Scientific Publications. Oxford, London.

May, R.C. (1970). Feeding larval marine fishes in the laboratory: a review. Rep. Calif. Coop Fish Invest. 14, 76-83.

Mazid, M.A; Y. Tanaka, T; Katayama M; Asadi - Rahman, K.L Simpson and C.O. Chickester (1979). Growth response of Tilapia zillii fingerlings fed isocaloric diets with variable protein levels. Aquaculture 18: 112-115.

Mcdowall R.M. (1970). The galaxiid fishes of New Zealand. Bull. Mus. Comp. Zool., 139: 341-431pp.

Mertz, E.T. (1972). The protein and amino acid needs, In: Fish Nutrition ed. J.E. Halver (ed.).Academic Press. New York, 105-143pp.

Milikin, M.R. (1982). Qualitative and quantitative nutrient requirements of fishes: a review. Fish. Bull. 80: 655-686.

Miliyenko, A.V. (1979). The assimilation of food by juvenile fishes. Hydrobiol. J. 15(6): 105-106.

Mito, S.M., Ukawa, and M. Higuchi (1969). In Lee, C. Hu, F. and Hirano, R. (1981). Organisms suitable as food for larvae of black sea bream. Prog. Fish - Cult, 43(3): 121-123.

Moriarty, C.M. and D.J.W. Moriarty (1973). Quantitative estimation of the daily ingestion of phytoplankton by Tilapia nilotica and Haplochromis migripinnis. J. Zool. 171: 41-55.

Munson, W.J., Harper, E.A., Benton, D.A. and Elvehjen C.A. (1954). The effect of level of dietary protein on the growth of chicks fed purified diets containing sucrose or dextrin. J. Nutr. 53: 563p.

Murray, M.W; J.W. Andrews and H.L. De loach (1977). Effects of dietary lipids, dietary protein and environmenta temperature on the growth, feed conversion and body composition of Channel catfish. J. Nutr; 107: 272-280p.

Nail, M.L. and Shell, E.W. (1962). The protein requirement of channel catfish Ictalurus punctatus. Proc. S.E. Assoc. Game Fish Comm. 16: 220-225p.

NFDC, (1979). National Fisheries Department Committee. The study of problems of aquaculture in Nigeria. A report of the NFDC. Federal Department of Fisheries, Lagos, 1979.

Nickum, J.G. (1978). Intensive culture of walleyes: the state of the art. Am. Fish. Soc. Special Pub. 11: 187-194.

Niimi, A.J. and Beamish, F.W.H. (1974). Bioenergetics and growth of large mouth bass (Micropterus salmoides) in relation to body weight and temperature. Canadian journal of Zoology 52: 447-456.

Nikolsky, G.V. (1963): The ecology of fishes Academic Press, London and New York. 352pp.

Nikolsky, G.V. (1969). Theory of fish population dynamics. Oliver and Boyd. Edinburgh, 323pp.

Nose, T. (1971). Determination of nutritive value of food protein in fish. III. Nutritive value of casein, white-fish meal and Soybean meal in rainbow fingerlings. Bulletin of freshwater Research Laboratory, Tokyo, 21: 85-98.

Nose, T. (1979). Summary report on the requirements of essential amino acids for carp. In: Halver J.E. and Tiews, K. (eds.) Finfish Nutrition and Fishfeed Technology, Vol. 1. 145-156. Berlin, Heenemann.

Nose, T. and Arai, S. (1972). Optimum level of protein in purified diet for eel, Anguilla japonica. Bull of freshwater Fish Res. Lab. 22: 145-155.

N.R.C. (1973) National Research Council. Nutrient requirements of trout, Salmon and catfish. National Academy of Sciences. Washington D.C.

N.R.C. (1976). National Research Council Nutrient requirements of warm water fishes. National Academy of Science, Washington, D.C.

N.R.C. (1977). Nutrient requirements of warmwater fishes. Nutrient requrements of domestic animal series. National Academy of Science. Washington, D.C.

N.R.C. (1983). National Research Council Nutrient requirements of warm water fishes National Academy of Science, Washington D.C.

Odimayo, O.A. (1986). Growth response and nutrient utilization of three size groups of Sarotherodon galilaeus (Linnaeus) fed on artificial diets. M.Sc. Thesis, Univ. of Ibadan.

Ogino, C. and Saito (1970). Protein nutrition in fish. 1. The utilization of dietary protein by young carp Bull Jpn Soc. Scc. Fish. 36, 250.

Ogino, C., and Watanabe, T.(1978). Nutritive value of proteins contained in activated sludge. photosynthetic bacteria and marine rotifer for fish. In E.L. Torrans (1982). Fish/plankton interaction. Principles and practices of pond aquaculture. J.E. Lannan, R.O. Smitherman and G. Tchobanoglous (eds). Oregon State University Press. Oregon.

Ogino, C. Chiov, T.Y. and T.Takeuchi (1976). Protein nutrition in fish. VI. Effects of dietary energy sources on the utilization of protein by rainbow trout and carp Bull. Jap. Sco. Sci. Fish 42: 213-218.

Olaleye, V.F. (1990). The effects of dietary protein quality on growth and body composition of Sarotherodon galilaeus Trewavas (Syn. Tilapia galilaea. Artedi) fed on formulated diets. Ph.D. Thesis, University of Ile-Ife, Ile-Ife, Nigeria.

Ogungbonna, A.A. (1980). In Ogungbonna, A.A(1986). The effects of artificial feedstuff and life zooplankton on the growth of fry of Clarias gariepinus (Burchell, 1822). M. Tech. (Aquaculture) Thesis, River State University of Science and Tech, Port-Harcourt, Nigeria.

Ogunghonna, .A. (1986). The effects of artificial feed stuffs, and live zooplankton on the growth of fry of Clarious gariepinus (Burchell, 1822). M. Tech. (Aquaculture) Thesis: River State Univ. of Sci. and Tech., Port-Harcourt, Nigeria. 60pp.

Okamota, O. (1969). In Lee C; Hu, F and Hirano, R (1981). Rearing of black sea bream larva. Prog. Fish Cult. 43(3), 121 - 123p.

Omotosho, J.S. (1985). Gonad structure, embryonic and larval development in two cichlids Tilapia zilli (Gervias) and Sarotherodon niloticus (Limnaeus Trewavas).

Osborne, T. and Mendel, L.B. (1919). A method of expressing numerically the growth promoting value of proteins. J. Biol. Chem. 37: 223.

Otubusin, S.O. (1987). Effects of different levels of blood meal in pelleted feeds on tilapia. Oreochromis niloticus production in floating bamboo net-cages. Aquaculture, 65: 263-266.

Oyenuga, V.A. (1963). Problems of livestock nutrition in Nigeria. Nutr. Abstr. and Rev; 28: 985-991.

Oyenuga, V.A. (1969). The present and future stage of food and nutrition in Nigeria. Proc. 8th Inst. Cong. Nutr. Prague. Sept., 28-Oct 5: 601.

Oyenuga, V.A. (1972). Protein Nutrition in Nigeria. Proceedings of an international symposium "on protein food" held at Univ. of Ife, Ile-Ife, Nigeria. April 11th-13th 1981. 8-19p.

Oyenuga, V.P. (1973). Food and feeds of tropical Africa. In: Animal production in the Tropics. Ed J.K. Loosh, V.A. Oyenuga and G.M. Babatunde. Heineman educational books Nig (Ltd) Ibadan.

Oyenuga, V.A. (1980). Nigeria Foods and Feeding Stuffs. Ibadan University Press, Nigeria.

Page, J.W. and Andrews, J.W. (1973). Interactions of dietary levels of protein and energy on Channel catfish (Letalurus punctatus). J. Nutr. 103-1339

Papoutsoglou, S.E. and Papaparaskeva-Papoutsoglou, E.G (1978). Comparative studies on the body composition of rainbow trout (Salmo-gairdneri) in relation to type of diet and growth rate. Aquaculture 13: 235-243.

Parameswaran, S., Selvaraj, C. and S. Radhakrishnan. (1974). Observations on the biology of Labeo gonius (Hamilton). Indian J. Fish. 21: 54-75.

Parker, R. and Vainstone, W.E. (1966). Changes in chemical composition of central Columbia pink salmon during early sea life. J. Fish. Res. Bd. Can. 23: 1353-1384.

Perera, P.A.B. and S.S. De-Silva (1978) Studies on the chemical biology of young grey mullet, Mugil cephalus L. J. Fish Biol., 13: 297-304.

Phillips, A.M. and Podoliak D.R. (1957). Nutrition of trout fish. Res. Bull. No 21. State of New York conservation Dept. Albany. 93p.

Phillips, A.M. Poston,H.A).R. Brockway (1957). Nutrition of trout 10. Vitamin requirements. Prog. Fish Cult. 19: 119.

Phillips, A.M. Jr. H.A. Podoliak, H.A. Poston, D.L. Livingstona, H.E. Booke, E.A. Pyle and C.L. Hammar (1963). Cortland Hatchery Report No. 26, State of New York Cons. Dept. Albany. New York.

Phillips. A.M. Jr., D.L. Livingstone, and Poston, H.A. (1966). The effects of changes in protein quality, calorie sources and caloric levels upon growth and chemical composition of brook trout. In Fish Res. Bull., 29: 6-7.

Pillay,T.V.R.(1968). Advances in Aquaculture. FAO Tech Conf. on Aquaculture. Japan. 567-578p.

Poston, H.A. (1975). Influence of dietary protein and energy on growth and body composition of brown trout. Prog. Fish-Cult. 37. 257-261.

Qasim, S.Z. Qayyum, A. (1961). Spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occuring in plains of northern India. Cited by Geevarghese, C. and P.A. John Maturation and spawing of a gobiid fish Oligolepis acutipennis (Cuv. and Val.) from the south-west coast of India, J. Fish. Biol. 23: 611-624.

Reay, P.J. (1979). Aquaculture (The Institute of Biology's studies in Biology: No. 106). University Park Press, Baltimore 60pp.

Ricker, W.E. (1975). Computation and Interpretation of biological statistics of fish population. Bull. Fisheries Res. Bd. Can. 191 382p.

Roy, D.C. and A.B. Gupta. (1973). Studies on the effect of feeding Cirrhina mrigala (Ham) and Labeo rohita (Ham) with Chlamydomonas species Labodeu. J.Sci. Tech. 11B(3-4): 53-58.

Sadykhov, D.A., I.B. Bogatovoa, and V.I. Filatou (1975). The amino acids in certain representatives of the fresh water zooplankton. Hydrobiol. J. 11(6): 39-42.

Sampson, E.O. (1955). A double duty oxidation pond. In: R.L. Applegate (1981) Food selection of Muskellunge fry. Prog. Fish-cult. 43:3. 136-139.

Satia, B.P. (1974). Quantitative protein requirements of rainbow trout. The progressive fish culturist 36: 80-85.

Scott, D.B.C. (1974). The reproductive cycle of Mormyrus kannume Forsk. (Osteoglossomorpha, mormyriformes) in Lake Victoria, Uganda. J. Fish Biol. 6: 447-454.

Scott, D.B.C. (1979). Environmental Timing and the control of reproduction in Teleost fish. Symp. Zool. Soc. Lond. No. 44. 105-132.

Seaton and Bailey (1971). The identification and development of the eggs and larvae of the blue whiting Micromesistius poutassou. Citation in S.H. Coombs and A.R. Hiby (1979). The development of the eggs and early larvae of blue whiting and effect of temperature on development. J. Fish Biol. 14: 111-123.

Shatunovskii, M.I. Novikou, G.G. (1971). Changes in some biochemical indices of the muscles and blood of sea trout during ripening of the sex products. In Love R.M. (1983). Chemical biology of fishes. Academic Press. London, New York. 943p.

Shatunovskii, M.I., Bogoyaulenskaya, M.P., Vel'tishcheva, I.F. and Maslennikova, N.V. (1975). Studies on generative metabolism in Baltic cod. In Love R.M. (1983). Chemical biology of fishes. Academic Press. London. New York. 943.

Shchepkin, V. Ya. (1971). Dynamics of lipid composition of the scorpion fish (Scorpaena porcus L) in connection with maturation and spawning. In Love, R.M. (1983). The Chemical biology of fishes. Academic press. London. New York. 943p.

Shelboure, J.E. (1965). Rearing marine Fish for commercial purposes. California cooperative oceanic fisheries Investigation Report, Vol. 10: 53-63p.

Shell, E.W. (1963). Effects of changed diets on the growth of channel catfish. Trans. Am. Fish Soc., 92: 432-434.

Shevchenko, V.V. (1972). Dynamics of the content of dry fat-free residue and of lipid content in the body and organs of the North Sea Haddock (Melanogrammus aeglefinus) (L.) in the course of growth and gonad maturation. In Love R.M. (1983). Chemical biology of fishes, Academic Press. London, New York 943p.

Shiau, S.Y. Chuang, J.L and Sun, C.L. (1987). Inclusion of soybean meal in tilapia (Oreochromis niloticus O. aureus) diets at two protein levels. Aquaculture 65: 251-261.

Shulman, G.E. (1974). Life cycles of fish. Physiology and Biochemistry. John Wiley and Sons. New York and Toronto.

Siddiqui, A.Q; Howlader, M.S. and Adam, A.A., (1988). Effects of dietary protein levels on growth, feed conversion and protein utilization in fry and youg Nile tilapu Oreochromis niloticus. Aquaculture 70;63-73.

Sivanlingram, S. (1975). Biology of Chrysichthys nigrodigitatus. Symposium on Aquaculture in Africa. Accra, Ghana, 30th Sept - 2nd Oct. 1975.

Smith, R.R. (1978). Methods for determination of digestibility and metabolizable energy of feedstuffs for finfish. Proc: Symposium on finfish nutrition and feed technology. Hamburg, Germany. 20th - 23rd June, 1978, 1 - 12p.

Smith, R.R. (1980). Nutritional bioenergetics in fish. In fish feed technology UNDP/FAO, ADCP/Rep/80/11. 21 - 27pp.

Smith, R.L., Paul, A.J. and J.M. Paul (1990). Seasonal changes in energy and the energy cost of spawning in Gulf of Alaska Pacific cod. J. Fish. Biol. 36, 307 - 316.

Spectorova, L.V., T.M. Aronovich, S.L. Doroshev and V.P. Popova (1974). Artificial rearing of the black sea turbot larvae (Scophthalamus maeoticus). Aquaculture 4: 319 - 341.

Stancey, N.E. (1985). Control of the timing of ovulation by exogenous and endogenous factors. In Fish reproduction, Academic Press Inc. Lond. Ltd. 208 - 222p.

Stancey, N.E., A.F. Cook and R.E. Peter (1979). Spontaneous and gonadotrophin-induced ovulation in the goldfish, Carassius auratus (L): effects of external factors. J. Fish Biol. 15: 349 - 361.

Stephen, W.P., Jr. (1976). Feeding of laboratory reared larvae of sea bream Archosargus rhombiodalis (Sparidae). Mar. Biol. 38; 1 - 16.

Stickney, R.R. (1977). Lipids in Channel catfish nutrition. In R.R. Stickney and R.T. Lovell (eds.). Nutrition and feeding of channel catfish. Southern Cooperative series Bulletin 21p.

Stickney, R.A. and J.W. Andrews (1972). Effects of dietary lipids on growth food conversion, lipid and fatty acid composition of Channel catfish. J. Nutr. 102: 249 - 258.

Stickney, R.R. (1979). Principles of warm water Aquaculture. John Wiley and Sons, New York. 375p.

Storoshuk, A. Ya (1975). Seasonal dynamics of the physiological-biochemical condition of the pollack from the North sea. In R.M. Love, (1983). The chemical biology of fishes. Acaemic Press London. New York, 943p.

Stroband, H.W.J. and Kroon, A.G. (1981). The development of the stomach in Clarias lazera and the intestinal absorption of protein macromolecules. Cited by Verreth, J. Storch, V. and Segner, H. (1987). A comparative Study on the nutritional quality of decapsulated Artemia cysts micro-encapsulated egg diets and enriched dry feeds for Clarias gariepinus (Burchell) larvae. Aquaculture, 63: 269 - 282.

Stroband, H.W.J. and Dabrowski, K. (1982). Morphological and physiological aspects of the digestive system and feeding in fresh water fish larvae. In: Verreth, J. Storch, V. and Segner H. (1987). A comparative study on the nutritional quality of decapsulated Artemia cysts, Micro-encapsulated egg diets and Enriched dry feeds for Clarias gariepinus (Burchell) larvae. Aquaculture, 63: 269 - 282.

Sukhanova, Y.R. (1968). The role of cyclops of (Acanthocyclops vernalis Fisch) in the survival of silver carp (Hypophthalmichthys) larvae.

Tacon, A.G.J. and C.B. Cowey (1982). Fish Nutrition Proceedings. 2nd International Conference on Aquaculture Nutrition. WMS Spec. Publ. No. 2 Louisiana State Univ. Press. Baton Rouge, VA 13 - 30pp.

Tacon, A.G.J. and C.B. Cowey (1985). Protein and amino acid requirements In: Fish energetics. New Perspectives. P. Tytler & P. Callow (eds.) Croom Helm. London & Sydney.

Takeuchi, T.; Watanabe, T. and Ogino, C. (1978). Optimum ratio of protein to lipid in diets of rainbow trout. Bull. Jap., Soc. Sci. Fish. 44(6): 683 - 688.

Talabi, S.O. (1982). Lipid stability of developed fish meat analogues from mince of Trachurus trachutrus, Ph.D. Thesis, University of Ife, Ile-Ife, Nigeria.

Tarma, G. and L. Horvath (1976). Growth of cyprinids under optimal zooplankton conditions. Bamidgeh 28: 50 - 56.

Thompson, D.W. (1963). On growth form. Cambridge University Press.

Tiemeier, O.W., C.W. Deyoe, and S. Weardon (1965). Effects on growth of fingerling channel catfish of diets containing two energy and two protein levels. Trans. Kans. Acad. Sci. 68: 180 - 186.

Turuk, T.N. (1972). Variations in the relative weight of the liver of Atlantic cod. In R.M. Love (1983). Chemical biology of fishes. Academic Press. London. New-York 943p.

Ursin, E. (1979). Principles of growth in fishes. In: Milder P.J. (ed.). Fish phenology: Anabolic Adaptiveness in Teleosts. 63 - 87pp. New-York, Academic Press.

Ursin, E. (1979). Principles of growth in fishes. Symp. Zool. Soc. London, 44: 63 - 87.

Utne, F. (1979). Standard methods and terminology in finfish nutrition: In J.E. Halver and T. Tiews (eds.) Finfish Nutrition and Fishfeed Technology, H. Heenemann GmbH and Co., Berlin, Vol. II, 437 - 444.

Underwood, E.J. (1977). Trace elements in human and animal nutrition (4th ed.) Academic Press, New York.

Valtonen, T. (1974). Seasonal and sex-bound variation in the carbohydrate metabolism of the liver of white fish. Comp. Biochem. Physiol, 47A, 713 - 727.

Van-Limborgh C.L. (1979). Industrial production of ready to use for mass rearing of fish larvae. In J.E. Halver and K. Tiews (editions), Finfish Nutrition and fish feed Technology, Heenemann, Berlin, Vol. 2, 3 - 11pp.

Vander-Wind, J.J. (1979). Feeds and feeding in fry and fingerling culture. In: E.A. Huisman and H. Hogendoorn (eds.) EIFAC Workshop on Mass rearing of fry and fingerlings of freshwater fishes/papers. EIFAC/FAO Tech. Papers 35, Suppl. 1159 - 72.

Verreth, J., Storch, V. and Segner, H. (1987). A comparative study on the nutritional quality of decapsulated Artemia cysts, microencapsulated egg diets and enriched dry feeds for Clarias gariepinus (Burchell) larvae Aquaculture 63: 269p

Viola, S. and Arieli, Y. (1982). Nutrition studies with tilapia (Sarotherodon). Replacement of fish meal by soybean meal in feeds for intensive tilapia culture, Bamidgeh, 35: 9 - 17p.

Viveen, W.J.A.R.; Richter, C.J.J. Van Dordt, P.G.W.J.; Janssen, J.A.L. and Huisman, E.A. (1986). Practical manual for the culture of the African catfish Clarias gariepinus. Ministry for Development Cooperation, Section for Research and Technology. The Netherlands.

Wang, K.W. Takeuchi, T. and Watanabe, T. (1985). Effects of dietary protein levels on growth of Tilapia niloticus. Bull. Jpn. Soc. Sci. Fish; 51: 133 - 140.

Watanabe, T. and F. Takashimo (1977). Effect of Tosopharo deficiency on carp VI. Deficiency symptoms and changes of fatty acid and triglyceride distributions in adult carp. Bull. Jap. Soc. Sci. Fish. 43(7): 817 - 830.

Weighs and Moser, (1981). In Pitcher, T.J. and Hart, P.J.B. (1982). Fisheries ecology, The Avi publication company, Inc., West Port Connecticut, 107 - 147pp.

W.H.O. (1965). World Health Organization: In Bell, F.W. (1975). Food from the sea. The economics and politics of ocean fisheries. Westview Press, Boulder Colorado.

Wilson, R.P. (1979). Carbohydrates in catfish nutrition. In R.R. Stickney and R.T. Lovell (eds.). Nutrition and feeding of Channel catfish. Southern Cooperative series Bulletin 21p.

Winfree, R.A. and Stickney, R.R. (1981). Effects dietary protein and energy on growth, feed conversion efficiency, and body composition of Tilapia aurea. J. Nutr. 111: 1001 - 1012

Wingfield, J.C. and Grimm, A.S. (1977). Seasonal changes in plasma cortisol, testosterone and oestradiol - 1713 in the plaice Pleuronectes platessa L. Gen. Comp. Endocrinol. 31: 1 - 11p.

Wootton, R.J. (1985). Energetics of Reproduction. In: Fish energetics New perspectives. P. Tytler and P. Calow (eds.) Croom Helm Publ. London. Sydney 1985.

Wootton, R.J. and Mills, L.A. (1979). Annual cycle in female minows Phoxinus phoxinus (L) from an upland Welsh Lake. J.Fish. Biol. 14: 607 - 618.

Wootton, R.J., Evans, G.W. and Mills, L.A. (1978). Annual cycle in female three-spined sticklebacks (Gasterosteus aculeatus) from an upland and low-land population. J. Fish. Biol. 12, 331 - 343.

Woynorovich, E. (1960). Breeding of pike, perch larvae to predatory age. In: W.F. Krise and J.W. Meade (1986). Review of the Intensive culture of Walleye fry. Prog. Fish-cult. 48, 81 - 89.

Woynarovich, E. and Horvath (1980). The artificial propagation of warm-water fishes. A manual for extension, FAO fish technical paper 207, Rome.

Yamamoto, K., Nagahama, Y. and Yamazaki, F. (1966). A method to induce artificial spawning of goldfish all through the year.
In: N.E. Stacey (1979). Control of the timing of ovulation by exogenous and endogenous factors. In Fish Reproduction Academic Press Inc. Lond. Ltd.

Yu, T.C., Sinnhuber, R.O. and Putnam, G.B., (1977). Use of swine fat as an energy sources in trout rations. Prog. Fish-cult. 39: 95 - 97.

Zahnd, J.P. (1959). Cited by Delahunty, C. and V.L. De-Vlaming (1980). Seasonal relationships of ovary weight, liver weight and fat stores with body weight in the goldfish, Carassius auratus (L.) J. Fish Biol 16: 493 - 504.

Zietler, M.H. - Kirchgessner, M. and F.J. Schward (1984). Effects of different protein and energy supplies on carcass composition of carp (Cyprinus carpio L). Aquaculture, 36, 37 - 48.

Zeitoun, I.H; Tack, P.I. Halves, J.E. Ullrey, D.R. (1973). Influence of salinity on protein requirements of rainbow trout Salmo gairdneri fingerlings. J. Fish Res Board, can 30 1867 - 1873.

Zeitoun, I.H. Ullery, D.E., Halver, J.E., Tack, P.I. and Magee, W.T. (1974). Influence of salinity on protein requirement of Coho salmon (Oncorphynchus kisutch) Smolts. J. Fish. Res. Bd. Can. 31: 1145.

Ziecik,M. and Nodzniski, J. (1964). Chemical and Weight composition of the comestible parts, waste and gonads of flounder (Pleuronectes flesus) during an annual cycle. In: Love,R.M. (1983). Chemical biology of fishes. Academic Press, London, New York.

Zuckerman,S. and Baker,G. (1977). The development of the ovary and process of oogenesis. In: The Ovary, 2nd Edn.Vol.1, 41 - 67pp. London Academic Press Inc.

Appendix 1

Composition of Vitamin-mineral Premix (per kg. of diet)

Vitamin A	=	9823 U.
" D_3	=	1965 "
" B_{12}	=	10.00 mg
Riboflavin	=	41.00 mg
Niacin	=	246.00 mg
Pantothetic acid	=	98.00 "
Folic acid	=	10.00 "
Manganese	=	341.00 "
Copper	=	244.00 "
Zinc	=	100.00 "
Iodine	=	20.00 "

Appendix II

Proximate composition of the experiments diets (%)

Diet	Protein	Moisture	Ash	Crude fibre	Fat
1	40.10	7.54	8.36	6.41	8.41
2	34.97	7.42	7.98	6.10	8.35
3	30.05	7.25	8.12	6.63	8.16
4	34.96	7.60	8.69	6.76	8.15
5	20.43	7.12	7.12	8.21	8.20
6	15.23	7.32	8.01	5.95	8.10

Appendix III - Food consumption per forthnight (FCF) and protein intake (PI) of C. nigrodigitatus fingerlings

Growth Parameters	Period	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	S.E	SIG
FCF	Week 2	4.02 ± 0.25^{a}	3.93 ± 0.27^{a}	3.96 ± 0.25^{a}	3.78 ± 0.22^{a}	3.80 ± 0.27^{a}	0.04005	n.s
	" 4	5.16 ± 0.22^{a}	4.99 ± 0.28^{a}	4.43 ± 0.28^{b}	4.14 ± 0.27^{c}	4.05 ± 0.25^{c}	0.0812	*
	" 6	6.31 ± 0.18^{a}	6.20 ± 0.21^{a}	5.22 ± 0.23^{b}	4.68 ± 0.22^{c}	4.28 ± 0.22^{d}	0.1330	*
	" 8	7.92 ± 0.14^{a}	7.76 ± 0.21^{a}	6.42 ± 0.22^{b}	5.26 ± 0.20^{c}	4.54 ± 0.22^{d}	0.2158	*
	Mean value	5.85 ± 1.67^{a}	5.72 ± 1.65^{a}	5.01 ± 1.08^{ab}	4.47 ± 0.65^{b}	4.17 ± 0.32^{b}	0.1335	*
PI	Week 2	1.61 ± 0.10^{a}	1.38 ± 0.095^{b}	1.18 ± 0.074^{c}	0.95 ± 0.06^{d}	0.76 ± 0.05^{e}	0.04955	*
	" 4	2.06 ± 0.086^{a}	1.75 ± 0.10^{b}	1.33 ± 0.084^{c}	1.04 ± 0.065^{d}	0.81 ± 0.05^{e}	0.0741	*
	" 6	2.52 ± 0.073^{a}	2.17 ± 0.075^{b}	1.57 ± 0.068^{c}	1.17 ± 0.053^{d}	0.86 ± 0.043^{e}	0.09921	*
	" 8	3.17 ± 0.057^{a}	2.71 ± 0.072^{b}	1.93 ± 0.065^{c}	1.32 ± 0.049^{d}	0.91 ± 0.047^{e}	0.1337	*
	Mean value	2.34 ± 0.67^{a}	2.00 ± 0.57^{a}	1.50 ± 0.33^{b}	1.12 ± 0.16^{bc}	0.84 ± 0.06^{c}	0.1831	*

Figures in the same horizontal row having similar superscript are not significantly different at ($P>0.05$).
* Significant at ($P<0.05$). n.s. = Not significant S.E. = Standard error.

Appendix IV - Protein intake (PI) and food consumed per forthnight by juveniles of C. nigrodigitatus.

Parameters	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	SIG
Protein intake (PI)	Week 2	3.18 ± 0.083^{a}	2.71 ± 0.086^{b}	2.24 ± 0.048^{c}	1.75 ± 0.012^{d}	1.34 ± 0.039^{e}	0.1199	n.s
	" 4	3.67 ± 0.11^{a}	3.04 ± 0.56^{b}	2.45 ± 0.49^{c}	1.90 ± 0.46^{d}	1.38 ± 0.024^{e}	0.1277	*
	" 6	4.31 ± 0.10^{a}	3.47 ± 0.07^{b}	2.66 ± 0.05^{c}	2.01 ± 0.044^{d}	1.43 ± 0.04^{e}	0.1641	*
	" 8	5.04 ± 0.14^{a}	3.94 ± 0.71^{b}	2.97 ± 0.058^{c}	2.12 ± 0.059^{d}	1.48 ± 0.035^{e}	0.2030	*
	Mean	4.05 ± 0.81^{a}	3.29 ± 0.53^{b}	2.58 ± 0.31^{c}	1.95 ± 0.16^{d}	1.41 ± 0.060^{e}	0.0673	*
Food consumed per forthnight (FCF) (gms)	" 2	9.08 ± 0.24^{a}	9.01 ± 0.28^{a}	8.95 ± 0.18^{a}	8.98 ± 0.21^{a}	8.95 ± 0.25^{a}	0.0361	*
	" 4	10.49 ± 0.31^{a}	10.13 ± 0.19^{a}	9.79 ± 0.19^{c}	9.50 ± 0.22^{cd}	9.21 ± 0.16^{e}	0.0727	*
	" 6	12.32 ± 0.29^{a}	11.51 ± 0.25^{b}	10.63 ± 0.20^{c}	10.03 ± 0.23^{d}	9.31 ± 0.25^{e}	0.1730	*
	" 8	14.41 ± 0.40	13.15 ± 0.24	11.98 ± 0.23	10.61 ± 0.29	9.85 ± 0.24	0.2683	*
	Mean	11.58 ± 2.31^{a}	10.95 ± 1.78^{ab}	10.34 ± 1.30^{bc}	9.78 ± 0.70^{bc}	9.33 ± 0.38^{c}	0.1764	*

Figures in the same horizontal row having similar superscript are not significantly different at ($P > 0.05$).

* Significant at ($P < 0.05$) n.s. = Not significant S.E = Standard error.

Appendix V - Protein intake and food consumed per forthnight of C. nigrodigitatus adult males

Parameters	Period	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Protein intake (PI)	Week 2	12.56 ± 0.065^{a}	10.51 ± 0.01^{b}	8.38 ± 0.047^{c}	6.31 ± 0.006^{d}	0.6029	*
	" 4	14.09 ± 0.074^{a}	11.73 ± 0.053^{b}	9.01 ± 0.09^{c}	6.50 ± 0.010^{d}	0.7360	*
	" 6	15.61 ± 0.062^{a}	13.18 ± 0.541^{b}	9.65 ± 0.034^{c}	6.64 ± 0.01^{d}	0.8788	*
	" 8	17.43 ± 0.063^{a}	14.45 ± 0.054^{b}	10.61 ± 0.030^{c}	6.93 ± 0.005^{d}	1.0216	*
	Mean	14.92 ± 2.08^{a}	12.47 ± 1.71^{b}	9.41 ± 0.952^{c}	6.60 ± 0.26^{d}	0.1824	*
Food consumed per forthnight FCF	Week 2	41.86 ± 0.21^{a}	42.02 ± 0.04^{a}	41.90 ± 0.22^{a}	42.01 ± 0.042^{a}	0.0392	n.s
	" 4	46.96 ± 0.25^{a}	46.93 ± 0.20^{a}	45.07 ± 0.42^{b}	43.32 ± 0.084^{c}	0.3932	*
	" 6	52.02 ± 0.20^{a}	51.72 ± 0.28^{a}	48.22 ± 0.17^{b}	44.56 ± 0.070^{c}	0.7840	*
	" 8	58.09 ± 0.21^{a}	57.78 ± 0.22^{b}	53.03 ± 0.16^{c}	46.16 ± 0.022^{d}	1.2445	*
	Mean	49.73 ± 6.95^{a}	49.61 ± 6.73^{a}	47.06 ± 4.78^{ab}	44.02 ± 1.78^{b}	1.3443	*

Figures in the same horizontal row having similar superscript are not significantly different at ($P > 0.05$)
* Significant at ($P < 0.05$). n.s. = Not significant S.E = Standard error.

Appendix VI: Food consumption per forthnight (FCF) and protein intake (PI) of the female adults of C. nigrodigitatus.

Parameter	Period	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	S.E	S.G
Food consumption per forthnight (FCF) (gm)	Week 2	42.22 ± 0.29^{a}	42.02 ± 0.11^{a}	42.25 ± 0.10^{a}	41.98 ± 0.15^{a}	42.09 ± 0.06^{a}	0.0887^{a}	n.s
	" 4	48.04 ± 0.09^{a}	47.07 ± 0.04^{b}	46.04 ± 0.00^{c}	44.54 ± 0.07^{a}	42.58 ± 0.07^{e}	0.0552	*
	" 6	53.93 ± 0.18^{a}	51.87 ± 0.21^{b}	49.27 ± 0.23^{c}	46.20 ± 0.04^{d}	42.72 ± 0.17^{e}	0.08124	*
	" 8	58.40 ± 0.03^{a}	58.57 ± 0.212^{b}	51.6 ± 0.08^{c}	47.82 ± 0.02^{a}	43.31 ± 0.66^{e}	0.0775	*
Protein intake (PI) (gm)	" 2	14.78 ± 0.11^{a}	12.59 ± 0.06^{b}	10.56 ± 0.03^{c}	8.40 ± 0.02^{d}	6.32 ± 0.00^{e}	0.04104	*
	" 4	16.81 ± 0.03^{a}	14.12 ± 0.014^{b}	11.50 ± 0.02^{c}	8.87 ± 0.014^{d}	6.39 ± 0.0071^{e}	0.0086	*
	" 6	18.88 ± 0.064^{a}	15.57 ± 0.064^{b}	12.32 ± 0.06^{c}	9.24 ± 0.01^{d}	$6.43\pm0.00\text{-}1^{4}$	0.0297	*
	" 8	20.44 ± 0.014^{a}	16.68 ± 0.064^{b}	12.90 ± 0.014^{c}	9.57 ± 0.0071^{d}	6.50 ± 0.0071^{e}	0.02415	*

Note - Figures in the same horizontal row having the same superscript are not significantly different at ($P > 0.05$).

n.s. = not significant

S.E. = Standard error

* = Significant at $P \leq 0.05$