FISH CULTURE STUDIES IN FLOATING CAGES IN LAKE KAINJI, NIGER STATE, NIGERIA.

BY

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FISH FOR THOUGHT

Remember some of our most wonderful inventions got off to SLOW STARTS as well:

* The first electric light was so dim that a candle was needed to see its socket.

* One of the first steamboats took 32 hours to chug its way from New York to Albany, a distance of 150 miles.

* Wilbur and Orville Wright's first airplane flight lasted only 12 seconds and

* The first automobiles travelled 2 to 4 miles per hour and broke down often. Carriages would pass them with their (carriages) passengers shouting, "Get a horse!"

BUT LOOK WHAT THESE INVENTIONS ARE CAPABLE OF TODAY! (Egner, D.C. (1990) Slow Starts. In: Our Daily Bread, 29 May, 1990. Vol. 35, Nos. 1, 2. Radio Bible Class, Grand Rapids, Michigan, U.S.A.)

So let it be with FISH CAGE CULTURE TECHNOLOGY IN NIGERIA!

DEDICATION

To the One God, the Father, the Creator of all things, including human beings to whom He gave dominion over the FISHES, the birds, and all the wild animals (and the entire earth).

Gen. 1:28.

DECLARATION

I, Samuel Olu. Otubusin, hereby declare that this dissertation is my own work and has not been presented in any form for another qualification at any other University or Institution. Information derived from the published or unpublished works of others has been duly acknowledged in this work.

Samuel Olu. Otubusin.
July, 1992.

CERTIFICATION

This dissertation entitled:

FISH CULTURE STUDIES IN FLOATING CAGES IN LAKE KAINJI, NIGER STATE, NIGERIA.

BY

SAMUEL OLU. OTUBUSIN

Meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

.....
Chairman, Supervisory Committee (PROF. A.A. OLATUNDE) Date: .....

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Dean, Postgraduate School (PROF. DALHATU MOHAMMED) Date: .....

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ABSTRACT

Fish culture studies were carried out in floating bamboo net-hapas and -cages in Lake Kainji area between 1986 and 1992 with the ultimate aim of evolving a fish cage culture technology appropriate for the use of fish farmers in inland waters of Nigeria.

Fourteen experiments were designed and carried out in five different locations around Lake Kainji involving general cage culturability of fish species, aspects of supplementary feeding, stocking densities, breeding (including hybridization) and utilization of natural productivity of either unpolluted freshwater or sewage water (without supplementary feeding) in fish production. The fish species used in the culture studies were:

Citharinus citharus, Distichodus rostratus, Oreochromis niloticus, Sarotherodon galilaeus, Tilapia zillii, Alestes dentex, Clarias gariepinus, Heterobranchus bidorsalis and Lates niloticus.

Completely randomized design was used to appropriately assign the treatments to the cages and the treatments were also appropriately replicated. All the nine fish species listed were used in the mixed culture experiment on general cage culturability while O. niloticus (ORN) and/or S. galilaeus (SAG) were consistently used in the breeding/hybridization

experiments and all the other experiments. The stocking densities ranged from 25 to 200 fish/m^3 for fingerlings while the breeders of ORN and/or SAG were stocked at 12 breeders/m^3 (with breeders male : female ratio varying from 1 : 1 to 1 : 5). The feeding experiments involved the use of either single ingredient feeds or compounded feeds in powdered or pelleted forms and were fed at feeding rates of 3% to 20% depending on the size of the fish, the objectives and duration of the experiments.

All the fish species in the mixed culture survived and grew except L. niloticus. The microphagous/ planktivorous species C. citharus, O. niloticus and S. galilaeus recorded high growth rates (2.03 to 3.31g/ fish/day). C. citharus, a highly fecund fish species was shown to be a potential candidate for culture in cages in addition to the popular tilapias.

In the feeding experiments: for nursery operations, a final combination consisting of 74% corn bran + 25% fish meal and 1% vitamin premix gave the fastest growth of fry to fingerlings with an FCR (Feed Conversion Ratio) of 1.13. For the grow-out phase, the best final feed formula (28.02% crude protein) consisted of 25% groundnut cake (as major protein source) + 74% corn bran/layer's concentrate (in ratio 3 : 1) + 1% premix with an FCR value of 1 : 12. The mean values of the FCR recorded for the feeds with different protein sources (soyabean meal, blood meal,

fish meal and groundnut cake) were significantly different ($P < 0.05$).

The growth rates of fish stocked at the different densities were observed to be inversely proportional to the stocking densities. Fish production, however, increased with increase in stocking density. The values of the mean total fish production, (kg/m^3) at stocking densities of 100 and 200 fish/m^3 were significantly different from those of 25 and 50 fish/m^3 ($P < 0.05$). Crosses of O. niloticus and S. galilaeus conducted in floating hapas in a near-to-nature environment were repeatedly successful and thus disproved the notion that these species do not readily hybridize.

In the pure-bred ORN fry production, breeders ratio of 1 male : 3 females gave the highest spawning frequency and highest fry production/month. Breeding success was much higher for the crosses that involved female ORN parent than those crosses involving female SAG parent. Heterosis was demonstrated only by hybrid progeny of the cross, male ORN x female SAG. Generally, the growth of the F_1 fingerlings (pure-bred) from the intraspecific crosses (i.e. all ORN breeders; all SAG breeders) was intermediate between the F_1 fingerlings (hybrid progeny) of the interspecific crosses (i.e. ORN males x SAG females; SAG males x ORN females).

Cage culture of Sarotherodon galilaeus was observed to have potentials in waste waters aquaculture. Recommendations were made on the execution of an integrated waste water management and utilization. The utilization of floating net-hapas and net-cages for commercial tilapia fingerlings and table-size fish production respectively were found to be technically feasible and economically viable.

Considering some technological gaps that still exist in the cage culture technology, recommendations were made towards achieving a total break through. Finally, the floating cage culture system (notable for use in existing bodies of water) was highly recommended to individuals, communities, governmental and non-governmental organizations and other interested bodies as one practical solution to the problem of unemployment and inadequate protein for the country's teeming population.

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CHAPTER 1

1. GENERAL INTRODUCTION

Nigeria is blessed with about 12.5 million hectares of water bodies (Ita et al., 1985). In addition, many irrigation reservoirs and canals have been built while some others are currently being built. The natural fish stock in these water bodies is being depleted daily as a result of over-fishing. This scenario has already been reported in the case of Lake Kainji (Otubusin, 1978; Ita, 1982). Since the local fish production in Nigeria is less than the demand, importation had been embarked on: in 1974, ₦7.3 million worth of stock fish and other fish and fish preparations were imported; ₦78.6 million was expended in 1977 and ₦141.4 million in 1978 (Federal Office of Statistics, (FOS) 1978). By 1984, the minimum total demand for fish in Nigeria was estimated as 1.35 million tons (Anonymous, 1974) and the production target in the same year as 1.1825 million tons. This target (estimated) production could only be viewed as an optimistic one because the actual total fish production was 241,000 tons (FAO, 1988). Whereas Ita (1986) estimated that the inland water mass of about 12.5 million hectares was capable of producing over 512,000 tons of fish annually if well managed.

Ayeni et al. (1986) further observed that less than 1% of these potential fish production sites was presently utilized for aquaculture. Otubusin (1983) opined that a judicious exploitation of all these available water bodies in aquaculture practices would surely contribute immensely to increased fish production in Nigeria.

Aquaculture, the rearing or farming of aquatic organisms has been recognized as a reliable alternative for increasing food production for the ever increasing population of the world especially the developing countries. It was therefore, not surprising that aquaculture development was one of the five programmes of action adopted by the 1984 World Conference on Fisheries Management and Development (FAO, 1985).

During the past decade, interest in the large-scale development of aquaculture, especially fish farming, as a manageable food production system has intensified considerably. Some of the reasons for the increase in these development efforts include:

- The growing demand for fish protein to meet the needs of rapidly increasing population
- The dwindling catch from capture fisheries even with increased

catching efforts

- The fact that production from aquaculture is related to manageable inputs e.g. control of the production process makes aquaculture less susceptible than capture "hunting" fisheries to unpredictable natural influences.

Aquacultural practices in Nigeria date back to the early 1940s (Anonymous, 1974). Pond culture of fish had all along been the focus of fish culture in Nigeria. The demonstration fish farms located at different parts of the country viz. Panyam (Plateau State), Oyo, Agodi and Iwo (Oyo State), Okigwe (Imo State), Akure (Ondo State), Wuya (Niger State) and Bagauda (Kano State), are but examples of the conception that pond culture of fish is the only aquacultural practice for fish production. It is therefore not surprising that cage culture of fish has had practically no application in Nigeria.

Cage fish farming had been traditionally practised for many years in several countries especially in Asia. Like most other types of aquaculture, cage culture was first practised in Southeast Asia (Ling, 1977). According to Pantulu (1979), the oldest records of cage culture come from Kampuchea (Cambodia) where fishermen around

the Mekong Basin usually held cat fishes and other commercial fishes captive in bamboo or rattan baskets and cages until ready for market. The captive fishes were fed kitchen wastes and were found to grow readily (Hickling, 1962; Huet, 1970). This practice later extended to Thailand for culture of sea bass (Lates calcarifer) in floating cages (Ling, 1967; Bardach et al., 1972). In Indonesia at the island of Java, bamboo cages placed near shore of the river rich in organic wastes produced 200 kg of carp (Cyprinus carpio) in four months without supplementary feeding (Huet, 1956; Hickling, 1962; Sodikin, 1977; Reksalegora, 1979). In Japan, the culture of yellow tail (Seriola quinqueradiata) and C. carpio in floating cages made of netting materials have become popular, and commercial production of 52,000 tons of fish from floating cages occupying less than 100 hectares of water surface had been reported (Furukawa, 1973). Brett (1974) noting the excellent results obtained in Japan proposed the introduction of the new technology to Canada. Milne (1974) reported the initial experimentation of cage culture at Laguna de Bay in the Philippines. Commercial cage/pen culture of fish is now famous in Laguna and Bunot Lakes in the Philippines (Anonymous, 1979; Guerrero, 1981).

In the last two decades or so, cage culture practice in inland waters had spread throughout the world to more than 35 countries in Europe, Asia, America and Africa, and by 1978 more than 70 species of freshwater fish had been experimentally cultured in cages (Coche, 1982). This new system of aquaculture has gained and continue to attract more interest and attention from many countries worldwide as one of the main alternatives for fish production. Among several examples are catfish farming in the United States of America; yellow-tail and red seabreams raising in Japan; the serranids culture in Hong Kong; tilapia/milkfish culture in the Philippines and the salmon and trouts raising in Norway and Great Britain are just few examples of the centres of greatest commercial activity utilising this innovation in aquaculture (Coche, 1978, 1979). Coche (1976) observed that cage fish culture offers great possibilities in Africa. In fact some successes have been recorded in fish cage culture in some African countries like Ivory Coast at Lake Kossou (Coche, 1975, 1977 and 1979; Shehadeh, 1974); Tanzania in Lake Victoria (Ibrahim et al., 1975), and recently in Egypt (Ishak, 1979, 1987; Ishak and Hassanen, 1987), Niger Republic (Ali, 1987); Togo (Issifou and Amegavie, 1987); Sudan (George et al., 1987) and Sierra Leone (Iscandari, 1987). In Nigeria, Konikoff (1975) was

the first person to study (just for a few months) the possibilities for cage culture of fish in Lake Kainji as well as in the Niger River immediately below the Kainji Dam. Konikoff (1975) noted the great potential for aquaculture in Lake Kainji area and recommended among others that experiments to determine the feasibility of cage culture in the lake should continue.

Cage fish farming which can be likened to the terrestrial animal production system (e.g. poultry farming in batteries of cages) is a very productive fish culture system utilizing existing water bodies (Anonymous, 1979). The fish stock is kept in the cage while water flows freely through it. The cage could be made of very fine-meshed (1.5mm mesh size) material commonly referred to as hapa for fish seed production in hatchery/nursery operations or of bigger-meshed nets (10mm mesh size minimum) or plastic netlon materials or even bamboo or wooden lattices for production of table-size fish. The cage could either be land-based (in pords or small reservoirs with regular exchange of water) or water-based (in large water bodies such as rivers, lakes, lagoons, coves, bays, mining paddocks). The cage could be floating (floating cage system) suspended in water as a single cage or modules (batteries) of cages or fixed (stationary cages) which are tied to vertical stakes at their corners.

Aside from the floating and fixed cage systems, the frame of the cages could be flexible or rigid (made of wood, galvanized iron pipes, PVC and bamboo).

Of the modern aquaculture systems, cage fish culture has been proven to be one of the cheapest to operate (Anonymous, 1979). This culture system requires limited investment, generally provides high returns on investment and utilized existing bodies of water. Incidentally, Nigeria is well endowed with vast water bodies and resources suitable for this fish culture system (cage), but the potentials are yet to be tapped. A rational exploitation of these water resources will entail a thorough production-oriented research. Since the ecological conditions in the suitable inland water bodies of Nigeria for this fish culture system may differ, there will be need for experiments using the cage culture system in selected representative water bodies in the country in order to establish the local specificity of the system. But because of the present financial constraint these studies were conducted around Lake Kainji Area using five different experimental sites with the following general aims and objectives:

a) to provide information on the potential of some readily available and commercially

important endemic fish species around Lake Kainji in cage culture system.

b) to identify which designs, materials and sizes are appropriate for fish broodstock development, seed production and the grow-out phase of the cage system.

c) to determine the effect of stocking density and supplementary feeding on the survival, growth and production of fish in the cage culture system.

d) to provide information on the economics of fish culture in the floating cage system in Lake Kainji area and

e) to evolve fish cage culture technology appropriate for the use of fish farmers in inland waters of Nigeria.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Criteria for Site Selection for Cage Fish Farm

Success of cage fish culture is largely determined by the selection of suitable site. The basic principles considered in site selection are good water quality, adequate water exchange and freedom from predators and natural hazards. These criteria are grouped as physical, physico-chemical, biological and other factors.

2.1.1 Physical Factors

2.1.1.1 Currents

Wind induced currents and other naturally occurring currents are expected to provide a continuous water exchange in the culture system thus keeping the dissolved oxygen (D.O) high and washing out the metabolites. However, the water current should not be strong enough to destroy the culture system or else stronger enclosure should be built. Muller (1976) recommended a strong cage structure for a current of about 2 knots or about 1m/sec. Coche (1976) recommended that cages be placed perpendicular to the principal water current. Chua (1979) observed water current of 0.2 to 0.5m/sec as adequate for optimizing production of estuary grouper in floating net cages.

2.1.1.2 Wind Directions

This factor affects the flow of natural food in the culture system, and will determine the growth of the fish under culture if the natural food in the water medium is the main source of food. It is therefore necessary to assess during site selection the degree of protection of the site from wind and wave actions. Records obtainable from the meteorological office for the site or its vicinity may provide an indication of the extreme conditions that are likely to prevail. Mok (1982) reported that areas with waves greater than about 0.5m in height would generally be unsatisfactory. Whereas, Chua (1979) found a wave height of 1m to be suitable for optimizing estuary grouper production in floating net-cages in Malaysia. However, Anonymous (1979) showed that the more protection afforded by the site for cage culture, the less would be the costs for anchorage and construction of extra strong cages and rafts, provided there is adequate circulation for water exchange.

2.1.1.3 Depth of the Water

Very deep lakes for example undergo thermal stratification during certain period annually. This situation often results in oxygen depletion at the deeper layer (hypolimnion) of the lake, non-circulation of nutrients in the water medium and

sometimes the release of toxic gases like hydrogen sulphide when mixing of the stratified layers takes place (Mok, 1982). Coche (1976) advised that cages should be 2 - 5m above the bottom sediments where numerous parasites may occur or where unconsumed food may accumulate. Felix (1982) observed that no less than five metres at low tide was suitable in inland seas or coastal areas.

2.1.1.4 Topography/Land Base

In general, Mok (1982) recommended a steep slope to shore leading to a flat bottom in 3 - 4m at the lowest tide as suitable for cage culture. An area of flat land adjacent to the site should also be available to provide a base for operation, accommodation of working staff and storage of equipment.

2.1.1.5 Texture of the Substratum

Cage culture system can be sited on almost any type of bottom. However, it is difficult to set up anchorages on rocky bottoms, whereas a very soft muddy bottom generally indicates low water exchange rate which is unsuitable for high density culture (Mane, 1982). A firm substrate of fine gravel, sand, mud or any combination of these would provide optimum conditions (Mok, 1982). But Felix (1982) opined that for cages in inland seas or coastal areas with a depth of five metres and greater, muddy, sandy or gravel bottoms are good sites.

2.1.1.6 Siltation, Turbidity and Floating Objects

Sites should be located away from flood paths which often lead to siltation, turbidity and increase the possibility of presence of heavy metals and other pollutants leached from the catchment area (Beveridge, 1987). Sites prone to water hyacinth and other floating objects infiltration should be avoided. Alferez (1977) noted that a fully grown water hyacinth plant can weigh as much as 10kg and occupy an area of 0.10m². He further estimated that a hectare of water hyacinth when compacted (total weight about 100 tons) and moving towards a floating fish cage system at the rate of 15cm/sec and 1 sec on impact can induce a force equivalent to 15.2 tons on the fish cage. In Jambi, Indonesia, Sodikin (1977) observed that high acidity brown water occurred as a result of the decomposition of leaves which have fallen within the catchmentarea leading to fish mortality in cages exposed to the water. He also observed that besides brown water, pollution problems occurred at Kalimantan, Indonesia, as a result of log harvesting operations. The cut ends of logs were painted with a chemical highly toxic to fish. When the logs were floated downstream, the chemical dissolved in the water causing widespread damage to fish cage culture. Cage culture sites, therefore, should be selected where there are limited habitation and industrial activities. Drainage and sewage

discharge from land into the water body should be away from the site and account should be taken of prevailing winds (Mok, 1982).

2.1.2. Physico-Chemical Factors

Among others, there are at least six physico-chemical characteristics that affect fish in the culture medium. These are temperature, dissolved oxygen, pH, ammonia, turbidity and pollution in form of toxic substances such as pesticides, oil, copper, arsenic and cyanide.

2.1.2.1. Temperature

The temperature of the culture medium profoundly influence the physiological and other related activities of all aquatic organisms. For example, many fishes reproduce, feed or migrate only within certain temperature limits which may be broad or narrow with respect to the species. Temperature also changes the solubility of gases like dissolved oxygen. Temperature affects not only the amount of available dissolved oxygen but also the rate of oxygen utilization by animals so that their effect on fishes must be considered together. Generally, the "comfortable" temperature range established for fishes is between 25 - 34°C (Santiago, 1982). A temperature range of 27 - 32°C was observed as optimal for optimizing production of estuary grouper in floating net-cages in lagoons and at the mouth of

rivers as in Kuala Semerak, Malaysia (Chua, 1979). Huet (1972) concluded that Tilapia sp could live within the temperature range of 8 - 40°C which would enable spawning exercise to occur. Caulton (1976) observed that Tilapia sp juveniles were thermophilic preferring temperature of 37°C and that they exhibited a distinct diurnal inshore movement which correspond to temperature above 23°C. Balarin (1979) concluded that it would appear that Tilapia sp could generally survive temperature of up to 38 - 40°C with some variation between species. In Lake Bainji, Tilapia and Sarotherodon species were found to live within temperature of about 35°C but a temperature of 42°C was considered as the upper lethal limit (Akintunde, 1976).

Another important use of temperature especially for deep water bodies such as lakes is that it helps in determining if the lake exhibits stratification. This is often monitored by temperature measurements from surface to bottom. Temperature had also been known to affect the concentration of dissolved oxygen in the culture medium. Dissolved oxygen concentrations were observed greatest at 0°C and decreased with increases of temperature (Boyd, 1979).

2.1.2.2 Dissolved Oxygen (D.O)

Aside from temperature, the D.O. content of the water is probably the most commonly measured parameter. Oxygen is essential to almost all life

so its shortage or absence affects or limits the abundance and distribution of animals and plants. Dondoroff and Shumway (1970) carried out extensive literature on the D.O. requirements of freshwater fish species. However, for practical purposes, Swingle (1969) considered that pond fish would die if exposed for long periods to less than 0.3mg/l D.O. He also stated that 1.0mg/l D.O. was the minimum concentration necessary to support fish at rest for long periods and concentrations below 5.0 mg/l were undesirable in ponds. Santiago (1982) also confirmed that good fish fauna were found in streams with D.O. over 5.0mg/l and that fish fed poorly at 2.0mg/l concentration. Caged Sarotherodon (Tilapia) niloticus in Ivory Coast survived D.O. concentration as low as 0.7mg/l for several days (Coche, 1980). However, Traore and Campbell (1976) observed that 64% of the adult fish and all the fingerlings in the culture system suddenly died within 3 days, when the DO dropped below 0.5mg/l. From observations, Coche (1982) concluded that it would appear that a DO of 3.0mg/l should be considered the limit in cage culture below which adverse effects begin to appear: feed digestion stops, the growth rate decreases sharply and stress intensifies. Coche (1981) reported that salmonids and warm water Crustacea should not be exposed to DO levels below 5mg/l for more than a few hours if good growth rates

were to be achieved. He noted that equivalent levels for eel, carp and tilapia might range from 4 to 3mg/l and that optimum levels were still higher. Chua (1979) observed a DO concentration of 3.0mg/l as ideal for optimizing estuary grouper production in floating net-cages in Malaysia.

It was also observed that channel catfish reduced their intake of supplementary feed during periods of low DO (Boyd, 1979). Stewart et al., (1967) observed that continuous exposure of large mouth bass to low DO produced similar effects. Continued exposure to low DO was also considered a precursor to bacterial infection in fish (Snieszko, 1973; Plumb et al., 1976). Supersaturation with atmospheric gases of waters falling over high dams was observed to cause gas bubble disease and mortality in fish living in streams below dams (Nebeker and Brett, 1976). In addition, DO concentration is particularly important in deeper lakes where overturn occurs during cold season when the deoxygenated bottom water is mixed with the upper layers.

2.1.2.3. pH

This is the measure of hydrogen ion concentration or acidity and alkalinity of water. The pH and its changes must be assessed since it may reflect biological activity and changes in natural chemistry

of water. Boyd (1979) noted that waters with pH values ranging from about 6.5 to 9.0 at day-break are most suitable. Swingle (1961) and Calabrese (1969) observed that the acid and alkaline points were approximately pH4 and pH11 respectively. Mount (1973) concluded that fish reproduction diminished at pH values below 6.5. Chua (1979) observed an optimal pH range of 7.5 - 8.6 for optimizing production of estuary grouper in floating net-cages in Malaysia.

2.1.2.4 Ammonia

Un-ionized ammonia (NH_3) is toxic to fish but the ammonium ion (NH_4^+) is non toxic (Downing and Merkens, 1955). The European Inland Fisheries Advisory Commission (1973) stated that toxic levels of NH_3 for short-term exposure usually lie between 0.6 and 2.0mg/l. Merkens and Downing (1957) observed that un-ionized ammonia was more toxic when DO concentration was low. However, this effect is probably nullified in fish ponds since carbon dioxide (CO_2) concentrations are susually high when DO levels are low. Lloyd and Herbert (1960) showed that the toxicity of NH_3 decreases with increasing CO_2 concentrations. A number of workers demonstrated that sublethal concentrations of NH_3 cause pathological changes in fish organs and tissues (Smith and Piper, 1975). Histological effects were attributed to continuous exposure to NH_3 concentrations of 0.006 to 0.34mg/l. Poor growth of fish in

culture tanks has also been attributed to accumulation of NH_3 (Andrews et al., 1971; Smith and Piper, 1975). Robinette (1976) reported that 0.12mg/l NH_3 caused reduced growth and gill damage in channel catfish. He did not notice any harmful effects of 0.06mg/l NH_3. Boyd et al., (1975) reported that high concentrations of total ammonia occur following phytoplankton die-offs, but abundant carbon dioxide associated with such events depresses pH and the proportion of the total ammonia present as NH_3. Coche (1981) concluded that the maximum tolerable concentration of un-ionized ammonia is about 0.1mg NH_3 - N/l although levels below this should be preferred. Ammonia is present generally as the end product of decomposition of nitrogenous organic matter. It may also be introduced from discharge of industrial wastes. Higher concentration of ammonia decreases the ability of the haemoglobin to combine with DO of blood and hence fish suffocate.

2.1.2.5 Turbidity

Turbidity due to inorganic material such as silt reduces light penetration. This affects natural food production i.e. limits photosynthesis. Wallen (1951) determined the direct effects of montmorillonite clay turbidity on 16 species of fish. Behavioural reactions occurred when turbidities exceeded 20,000 mg/l, but most individuals of all species survived

exposure to 100,000mg/l of clay turbidity for a week or longer. Appreciable mortality occurred at clay turbidities above 175,000mg/l. Turbidities in natural waters seldom exceed 20,000mg/l and even "muddy waters" usually have less than 2,000mg/l (Irwin, 1945). Eventhough turbidity caused by suspended soil particles will seldom have direct effects on fish it may adversely affect fish populations (Buck, 1956; Duchrow and Everhart, 1971). Sedimentation of soil particles may smother fish eggs and destroy communities of bottom organisms. Turbidity by plankton is not harmful to fish (Boyd, 1979).

2.1.2.6 Toxic Substances

There are a number of toxic elements to fish that may exist in lethal concentration in water. Some of these are: chlorine, pesticides, nitrites and nitrates (Boyd, 1979).

a) Chlorine

Both free and combined chlorine residuals are extremely toxic to fish (Tompkins and Tsai, 1976). White (1955) determined the lowest concentrations of free chlorine residual required to kill 100 per cent of test populations of four species of fish at 27°C. The values were: 0.02mg/l for fat-head minnows, 0.047mg/l for blue gills, 0.074mg/l for gold fish (Carassius auratus) and 0.079mg/l for golden shiners

(Notemigonus crysoleucas). Much lower concentrations of free chlorine residuals caused partial mortality of test populations. For example, the LC_{50} for blue gill at 27°C was 0.021mg/l. Therefore, if measurable concentrations of chlorine residuals are present in water, the water should not be considered safe for holding fish.

b) Pesticides

Many pesticides and insecticides in particular, are extremely toxic to fish. Acute toxicity values for many commonly used insecticides range from 5 - 100ug/l (Cope, 1964 and 1971) and much lower concentrations may be toxic upon longer exposure. Even if adult fish are not killed outright, long term damage to fish populations may occur in environments contaminated with pesticides. The abundance of food organisms may decrease, fry and eggs may suffer mortality, and growth rates of fish may decline (Cope, 1971). In site selection for a cage fish farm therefore, if the watersheds of the proposed site receive heavy applications of pesticides, the project is not suitable for that area.

c) Nitrites and Nitrates

During the fall of 1978, a number of fish kills were reported in Mississippi and Alabama in which fish mortality could not be attributed to low dissolved oxygen, parasites, diseases, or other common causes (Boyd, 1979). All dead or dying fish

had "chocolate" coloured blood which indicated that haemoglobin had been converted to methemoglobin. Nitrite poisoning results in methemoglobin formation, so nitrite toxicity was suspected as the cause of the fish kills. Tomasso et al., (1979) exposed channel catfish fingerlings for 24 hours to 1.0, 2.5 and 5.0mg/l of nitrite and noted methemoglobin levels of 21, 60 and 77 per cent respectively. Crawford and Allen (1977) noted that nitrite concentrations as low as 0.5mg/l were toxic to certain cold water species. Coche (1981) opined that based on limited available data, it was suggested that prolonged exposure of fish in hard, freshwater should not exceed 0.1mg NO_2 - N/l. In the case of nitrates, he noted that levels below 100mg NO_3 - N/l are satisfactory.

2.1.3 Biological Factors

2.1.3.1 Natural Plankton Productivity

The rate at which natural food is produced in an ecosystem determines to a great extent the amount of organisms including fish that can exist there. The natural plankton productivity of the lake is very important since the availability of food is a determining factor in fish growth. Santiago (1982) reported that a biomass of more than 10g/m^3 is good for fish culture and that a rich water contains 5 - 100mg chlorophyll (plant pigment) per m^3. He further noted that a primary production of about 5gC/m^2/day

seems to be a minimum value for good fish growth. Santiago (1982) observed an average cell count per ml of about 100,000 or roughly equivalent to 30g/m³ biomass from Laguna Lake, a eutrophic body of water flourishing with commercial pen and cage culture of tilapia and milkfish. He reported the primary productivity to be between 0.5 - 9.0gC/m³ day.

2.1.3.2 Excessive Fouling

The type of fouling organisms (e.g. algae, coelenterates, annelids, molluscs and simple chordates) at the site should be assessed in order to ascertain that the water of the site will not pose serious fouling problems. Sites with excessive fouling should be avoided. Detailed study of the seasonal pattern and effect of fouling on the cage culture system could entail actual testing, using the raft and cage materials at the proposed site for a period of 12 months (Beveridge, 1987).

2.1.3.3 Predation

The presence of a high density of fish in cages seems to attract a wide range of both facultative and obligate fish-eating vertebrates. The range of species which include fish; birds (e.g. herons, cormorants, egrets, ducks); snakes; rodents and mustelids (e.g. otters) have been reported to cause problems at cage and pen farms (Martin, 1982; Salmon and Conte, 1982; Ranson and Beveridge, 1983). Secretan (1979) reported that cage and penned fish

frequently escape through netting or mesh damaged by predators, floating objects or rough weather. In a lake in Poland, Penczak (1982) estimated that 4 tons of trout escaped in one year. In a fish farm, Beveridge (1984) observed that 0.5% of all caged fish showed evidence of birds damage, which could lead to secondary bacterial or fungal infection. Beveridge (1984) concluded that certainly mammals and birds play important roles in the life cycles of many commercially important endo-parasitic fish diseases. For example, birds act as intermediate host in the life cycle of the nematode, Contracaecum, and piscivorous mammals such as the otter may act as final host for the digenean Halplorchis, both common parasites of tilapia (Roberts and Sommerville, 1982). It is therefore, necessary, during site selection to note the presence of possible predators of the cultured species.

2.1.3.4 Diseases and Parasites

Sarig (1979) enumerated five main groups of organism which cause disease in fishes: ectoparasites and fungi; endoparasites; bacteria; viruses and organisms which produce toxins leading to fish deaths. The occurrence of disease outbreaks in fish farming is usually associated with bad husbandry, since the disease-causing organisms are often ubiquitous and cause few problems until the fish are stressed through inadequate dietary or environmental conditions

(Wedemeyer, 1970; Snieszko, 1974; Roberts and Shepherd, 1974; Shepherd, 1978). In several cases in the U.K., cage fish have become severally infested with the cestodes Triaenophorus nodulosus and Diphyllobothrium spp. resulting in heavy mortalities, and the eventual closure of one farm (Woctten, 1979; Farrams et al., 1980). Those infections were attributed to the wild fish population which were subsequently found to be carrying the parasites. A survey of fishes in a Scottish lake site prior to the introduction of cages showed no endo-parasites present, and one month later cages of rainbow trout were introduced. The stocked trout were also examined and found to be free from parasites. However, two months later mass mortalities of fish were reported, and on examination the fish were found to be heavily infected with Diphyllobothrium spp. (Beveridge, 1984).

Few such parasites or disease problems have been reported in cage or pen culture of fishes in the tropics, although Vass and Sachlan (1957) reported the presence of gut parasites in common carp grown under extensive conditions in a polluted stream in Indonesia. These parasites were believed to have been transmitted from human faeces.

2.1.4 Other Site Selection Factors

2.1.4.1 Availability of Efficient Fish Feed

Feed represents 40 - 60% of the total operating costs in intensive aquaculture including cage fish farming (ADCP, 1983). In addition, technical problems of feed manufacture and storage can hamper the development of intensive cage culture which has proven economically viable, and this is particularly true in the tropics. For example, expansion of the intensive cage culture of rainbow trout in Bolivia once faced problems due to the poor quality of commercially available diets (Beveridge, 1983). Contamination of feeds by aflatoxin-producing species of Aspergillus has also been reported as causing problems in tilapia farms in Africa and southeast Asia (Roberts, 1983; Olufemi et al., 1983).

2.1.4.2 Poaching

For example, theft and vandalism have been cited by cage tilapia producers in the Philippines as the major problems encountered by the operators (Escover and Claveria, 1983).

2.1.4.3. Conflict with Other Uses

The site should not conflict with other uses like for swimming, navigation and even generally aesthetics. For example, in many countries, provision is made within conservation laws to

preserve areas of outstanding natural beauty, and protect them from unsightly developments. The proposed establishment of a large floating cage farm in Loch Lomond, Scotland, by a private company was objected to by a number of those who thought that this would detract from the scenic value of the area, reduce tourist numbers estimated at 2 million per year, and ultimately affect local employment and incomes (Beveridge and Muir, 1982). Similar objections have been raised over the cage culture developments in Hong Kong (Beveridge, 1984).

2.2 Materials in Use for Cage Culture

The basic materials used for cage culture system design, construction and management are dependent on the culture system design, local supply, availability, and cost of the needed materials and the desired effects of results to be achieved (Gargantiel, 1982; Beveridge, 1987).

2.2.1 Cages

Cages are the enclosures in which the fish (i.e. breeders, fry and fingerlings) are kept captive such that there is sufficient water circulation through them (cages). A variety of materials are in use for the construction of cages in most countries. The materials range from the locally available items like wood and bamboo to manufactured items such as polyethylene and nylon nettings (knotted or knotless),

wire-mesh, plastic netting (e.g. Netlon type), or metal netting.

For hatchery/nursery operations small-meshed (1 - 3mm) materials are used to prevent the loss of fertilized eggs and the hatchlings. Guerrero and Garcia (1983) used a double-net cage consisting of an inner cage with 30-mm mesh and an outer net cage of fine mesh (1 - 3mm) net hapa in a lake-based hatchery at Laguna Lake, Philippines. Hughes and Behrends (1983) used hapas of knotless nylon, 1.6mm mesh for mass production of Tilapia nilotica seed at the Alabama Agricultural Research Station, Auburn University, Alabama, U.S.A. Dela Pena and Prospero (1984) reported on how to operate a floating nursery cage of nylon net, mesh 0.5mm held together by a frame work of bamboo poles for higher "sugpo" (prawn) survival and good harvest.

For grow-out operations, the choice of materials is important but the mesh size of the walls of the cage remains the most important factor. The mesh size should be as large as possible, according to the size of the fish being raised, to allow a free circulation of water through the cage at all times. In Lake Kossou, Ivory Coast, Campbell (1978) reported the use of nylon fibre netting 210/18 twine, 14mm mesh and plastic netting (8 and 25mm mesh, Netlon). Chua and Teng (1977) recommended an R 1150 to 1300

tex polyethylene netting (21 to 24-ply threads) for cages that would be used in crabs-ridden cage culture site. Pantastico and Baldia (1970) in experimental culture of S. mossambicus in Laguna Bay, Philippines, used cages of 5.4mm mesh for stocking fingerlings of 10g mean weight. Guerrero (1979) reported the use a polyethylene netting of 25mm mesh nailed to a wooden frame for experimental culture and nylon netting bag of 12.7mm mesh for commercial cage. In Ivory Coast, De Kimpe (1978) also used nylon netting bag of 14mm mesh in 210/18 twine as experimental cage. In Nigeria, Konikoff (1975) used poultry mesh cages with wooden frame for Tilapia cage culture trials in Lake Kainji. Whereas, Campbell (1985) under the large scale cage farming of Sarotherodon niloticus in the Ivory Coast used 8mm black plastic mesh (Netlon) for fingerling cage and 22mm plastic mesh for the body of the rearing cage. In Israel, Ben-Yami (1974) used nylon netting of 10mm stretch mesh, 210/6D for cages in rearing rabbit fish (Siganus rivulatus) fingerlings. In Indonesia, Christensen (1989) recommended ultraviolet-resistant and knotless netting as the best, 5mm stretch mesh for small fingerlings and 10 - 20mm for the culture of larger fish until they reach market size. In Malaysia, Chua (1979) used polyethylene netting of mesh sizes 6.4mm, 12.7mm and 25.0 to 38.0mm in constructing cages for culture

of estuary grouper below 5cm, between 15 - 20cm and above 21cm respectively. In Ontario, Canada at Linwood Acres Trout Farms, nylon nettings with mesh sizes 12.5mm - 50.0mm were used (Taylor, Pers. Comm.). In Scotland, Hull and Edwards (1979) used 12.7mm square aperture plastic coated welded mesh in constructing cages for rearing turbot, Scophthalmus maximus. In Indonesia, Costa-Pierce et al., (1989) developed rigid cage made of bamboo lattices, the mesh (or spacing between the lattices) of which was smaller than the width (or girth) of the smallest fingerlings stocked. The top of the cage was of wire mesh.

2.2.2 Framework (Raft)

In the case of rigid cage, the framework determines the size and shape of the cage, whereas it is to the framework or raft that flexible cages are attached especially in either the fixed or floating system. The framework or raft can be constructed either of wood, bamboo, metal or plastic materials. Flexible cages are generally made of conventional synthetic fishing net materials, usually nylon twine, formed into a bag shape. Rigid cages, on the other hand, are made from a wider range of materials, forming panels supported by rigid frames. Flexible cages made of synthetic netting are the most common, but rigid cages made

of galvanized weldmesh reinforced with galvanized scaffold pipes, are becoming popular. The latter are used commercially in Scotland for salmon, and the rigid cages of up to 1077m³ have been built in Japan (Milne, 1976).

Considering rigid cage, various materials are used for the framework: In Saguling and Cirata Reservoirs in Bandung, Indonesia, the entire cage including the frame are made of bamboo poles and splits (Costa-Pierce et al., 1989). In shallow inshore waters at Turicorin, India the cages are of three different types: basket type, rectangular box type cages, and metal framed synthetic twine mesh cages (Marichamy et al., 1979). The basket type cages were made entirely of cane splits closely woven in the form of a basket with a lid at the top. These cages were found suitable for the culture of young crabs (Marichamy et al., 1979). The box type cages were made of soft wooden planks. The cages were constructed with planks in such a way as to leave sufficient space between them to allow free circulation of water. In Nepal, iron angles of 13mm or 19mm were welded together to form a frame of 4 x 4 x 2.5m and Netlon plastic mesh of 10mm or 5mm was fixed with nylon twines to the angle-iron frame (Sharma, 1979). In the Philippines, Guerrero (1979) described a rigid 1m³ cage used for T. nilotica made of wooden frame to which was nailed

polyethylene netting (25mm mesh) as walls. In the Negombo Lagoon, Sri Lanka, Jayamaha (1979) experimented with five types of rigid cages:

i) cylindrical cage made of rigid copper wire frame covered with a 1/8 inch (about 3mm) mesh size nylon net;

ii) another cylindrical cage made of rigid copper wire frame but covered with a closely knit bamboo tats;

iii) a cage of wooden frame covered with nylon net of 3mm mesh size;

iv) another cage of wooden frame but covered with finely knit bamboo tats; and

v) a cage made of galvanized mesh.

In Thailand, the rigid cages are often box shaped constructed entirely with either wooden planks or galvanized wire mesh (Tangtrongpiros, 1979). In the Philippines, Dela Pena and Prospero (1984) reported about a rigid nursery cage made of nylon net held together by a framework of bamboo poles that was successfully used to ensure high sugpo (Penaeus monodon) survival and good harvest.

On the other hand, the framework for the non-rigid cages serve for hanging the cages either in the fixed cages system or the floating cage system. In the case of the fixed cage system, the framework is in form of structures or posts like bamboo poles, water resistant wood and galvanized iron pipes driven

into the substrate at the cage culture site and the cages are attached to them. In some parts of the world such as the Philippines and China, fixed cages are used in shallow waters (less than 8m depth) with appropriate muddy bottoms (FAO, 1983). Fixed cages are cheaper and simpler to construct since they do not involve the construction of a buoyant collar or float, which can account for more than 50% of the capital outlay (IDRC/SEAFDEC, 1979). However, fixed cages are often poorly constructed, and thus may be less able to withstand inclement weather conditions. For example, in July 1983 almost all of the fixed cages in Lake Buhi, Bicol Region in the Philippines were destroyed by "Typhoon Bebeng", whereas most of the floating cages survived (Beveridge, 1984).

In the floating cage system, the raft serves for hanging the net-cage. In the Philippines, the most commonly used material for raft construction is bamboo which also serve as floats (Gargantiel, 1982). Floating cages of this type are famous on Lake Bunot, San Pablo City, Philippines (Guerrero, 1981). Wood, plastic and galvanized iron are the other popularly used materials for the construction of raft. In India, Natarajan et al., (1979) used thick and sturdy bamboos of about 70 - 100mm in diameter, for making the raft which was fixed with iron bolts and nuts, enabling easy assembly, dismantling and transport.

In Indonesia, Jangkaru and Djajadiredja (1979) used steel bars in constructing a 10 x 10m raft for culturing common carp in floating net-cages. In Malaysia, Chua (1979) at a coastal site, used sea water resistant wood, Hopea odorata for the construction of raft since the wood could last more than four years when coated with anti-fouling paints. In Sierra-Leone, Iscandari (1987) constructed rafts with timber for culture of Tilapia nilotica. In the culture of yellowtail in Japan, rafts made of bamboo or galvanized steel are used (Mok, 1982). In the culture of Atlantic Salmon in Scotland, galvanized scaffolding tubes were used for raft construction whereas polystyrene covered by plywood was used in raft construction for Pacific salmon farming (Beveridge, 1987). In Europe, the elements of the raft are made of aluminium profiles filled with polystyrene foam (Mok, 1982). At SEAFDEC, Philippines, experimental raft was made of galvanized iron pipes (5.0cm in diameter) welded together (Gargantiel, 1981). In Singapore, Shiew (1981) reported that the raft was made from wood of 5.0cm x 7.5cm or 7.5cm x 10cm in size joined together with nails or nuts and bolts. Generally, the raft also serves as walkway or catwalk for the workers who manage the floating cage system.

2.2.3 Floats

The design of floatation materials is aimed at supportingthe weight of the raft, the wet net during retrieval, the people working on the structure and the fish harvest. Various types of floatation materials are in use all over the world. Generally, the selection of the type of floatation system is determined by several factors like cost, availability, durability, ease of replacement, effectiveness in a particular situation and its efficiency as a floatation system in relation to the investment in the culture system and the value of the stock (fish) contained.

In Thailand, the float types used are logs/ bamboo, steel drums, styrofoam, PVC and plastic containers (Tanomkiat, 1982). The bamboo poles, in bundles, were observed to last two years in freshwater, while the PVC materials though of lowered cost deteriorated faster due to effects of sunlight (Tangtrongpiros, 1979; Dhebtaranon et al ., 1979; Anon, 1979). Steel drum, plastic drum and spherical/ conical buoys are used in Singapore and for maintenance the drums are changed every six months (Watson and Raja, 1979). Float types in use in the Philippines are bamboo/logs, empty barrels, steeldrums, PVC pipes, fibre glass and ferrocement (Guerrero, 1979; Yu et al., 1979). Cabangbang (1979) reported that one metre long styrofoam float used in Philippines could support a load of 540kg. In Hungary plastic drum, PVC pipes,

styrofoam spherical/conical buoys and aluminium floats are used. Muller (1979) reported a life span of up to twenty years for latter type of float (aluminium). In India, bamboo poles,aluminium cylinders and painted steel drums are the commonly used floats. In Indonesia, at the Middle Mahakan Area, Christensen (1989), Reksalegora (1979), Jangkaru and Djajadiredja (1979) reported that many items including plastic jerrycans, PVC pipes, empty 200-l petrol drums, styrofoam blocks, bundles of bamboo tied together and tree trunks or logs could be used as floats. Christensen (1989) observed that logs were among the best materials in places where they are cheap, as they were least disturbed by large waves unlike other floatation devices. The rusting of petrol drums and the disintegration of plastic jerry cans due to the effects of the sun were reduced by painting them with heavy-duty tar paint.
Reksalegora (1979) observed a one to two years life for bamboo,five years for drum, and three to four years for light wood logs used as floats.
In Malaysia, 8-gallon plastic container, bamboo/logs styrofoam, oil drums coated with fibreglass and uncoated oil drums are the float materials used. The uncoated oil drums were reported to last two to three years in freshwater (Chua, 1979). Cement blocks as well as used types stuffed with styrofoam materials are observed to be satisfactory as floats for floating

cages (Chua, 1979). In Bangladesh, Cabangbang (1979) used 45-gallon oil drums painted with three coatings of coaltar as floats. In Egypt, bamboo poles, logs, steel drum, plastic drum and PVC pipes were used as floats (Ishak, 1979; 1985; Ishak and Hassanen, 1985). In Nepal, bamboo/logs, steel drum and spherical/ conical buoys are reported in use (Sharma, 1979). He observed that the rectangular bamboo frame which also served as float could last for about two years on water. In Sierra-Leone, bamboo/logs and steel drums were used as float. Dabo (1979), and Iscandari (1985) reported the use of empty 44-gallon (200-l) oil drums coated with a mixture of tar or pitch for floating the bamboo raft. Jayamaha (1979) reported the use of bamboo/logs and steel drums for experimental cages set up in the Negombo Lagoon in Sri Lanka. The commonest materials in use as floats in Hong Kong include bamboo (in bundles of poles), plastic drums, iron drums, plastic containers, styrofoam floats, aluminium cylinders and fibreglass floats (Mok, 1982). Their average lives in water range from less than one to over ten years (Mok, 1982).

2.2.4 Mooring Systems

The floating cage system is usually moored or anchored to a fixed locality to prevent its being tossed about or even washed away during inclement conditions. Most mooring systems consist of anchors

and lines. Several materials ranging from ordinary wood (tree trunks) to galvanized iron bars are in use as anchors while for the anchor lines the materials range from metal chains, steel cable, and wooden posts, to natural fibre ropes. The mooring systems are an extremely important part of a floating cage farming system because the mooring systems influence the safety of the staff working on the floating system, behaviour of the cages in inclement weather and can affect production and profitability. Little wonder that commercial fish cage manufacturers are increasingly willing to or even insistent that, they design and install the mooring system, otherwise they may refuse to cover the cages against structural failure (Beveridge, 1987).

Ideally, mooring requirements should be determined by the design and type of cages used and the characteristics of the site. The procedure for carrying out such a computation would be to quantify the incident forces that are likely to act on the cages under worst possible weather conditions that could occur at the site, and then to evaluate the propoction of energy that is absorbed by the cage or group of cages. Part of this energy should be transferred from the cage to the mooring lines and anchors, the respective roles of the cages and mooring system in dissipation of the energy being determined by the specifications and group

configuration of the cages and the costs of the mooring system (Beveridge , 1987). In spite of the above consideration, the materials in use for anchors and mooring lines are often determined mainly by availability and cost. For example, in Malaysia, Chua (1979) reported that floating cage unit was usually anchored by large metal anchors or by wooden pegs driven into the bottom unit. The cages could also be anchored from the land if they (the cages) were not far away from the shore. Chua (1979) further noted that the fish farmers usually abandoned the use of metal anchors in favour of wooden pegs. Cabangbang (1979) reported the use of 100kg cement anchors with 12mm diameter nylon rope as anchor line for floating cages at Kaptai Lake in Bangladesh. Marichamy et al. (1979) in the culture of fishes in cages along the coastal waters of India used heavy stones picked from the locality as anchors. In Indonesia, Jangkaru and Djajadiredja (1979) used 25kg concrete anchors in the common carp floating cage culture. In the Philippines, Yu et al. (1979) anchored the circular floating cages for milkfish broodstock production (at Igang Station of SEAFDEC, AQD) to the seabed using steel anchors attached to 20mm diameter poly propylene rope. They suggested that for more permanent locations, heavy concrete blocks, might be used as anchors. Gargantiel (1982) used 26.5kg metal anchor made of galvanized iron bars, 3.2cm in diameter for a floating cage unit with a framework of 10 x 5m,

12 styrofoam buoys and two net-cages 5 x 5 x 2.5m each. Mok (1982) described the design and construction of floating cages rafts in Hong Kong; that the cages were anchored in position at each corner by an iron anchor of about 30kg with polyethlene rope. He noted that in many cases, cement blocks were used instead of iron anchors and that this type of mooring device was more economical on account of its long life even though it was heavy and difficult to work with. Beveridge (1987) was of the opinion that block anchors were inefficient, that is, they have low holding power per unit installed weight. On the other hand, he concluded chat, in practice, block anchors could be more efficient than earlier suggested, since they (block anchors) tend to bed down into the substrate. There are numerous types of embedding anchors(normally made of metal) like Mush room; Kedge; Navy stockless; Lightweight; Danforth and Grapnel (Beveridge, 1987). The holding power of an embedding anchor is related to its frictional resistance in soil, and so is independent upon fluke area and soil penetration and the mechanical properties of the soil, rather than on the mass of the anchor (Milne, 1970). Anchor penetration, on the other hand, is a function of fluke-shape and the angle between the fluke and the shank whilst the frictional resistance of the soil is dependent upon soil cohesiveness and shear strength (Milne, 1970).

Beveridge (1987) concluded that embedding anchors are very efficient i.e. they have a high holding power to mass ratio. He further noted that under optimum conditions (sandy mud soil, low angle between mooring line and anchor, etc), they are between 10 and 100 times as efficient as block anchors.

The design of anchors, including their weight and number (per floating raft system) is often determined by the weight and size of the cages, nature of the bottom, current, tides, waves and winds prevailing at the location (Chua, 1979).

There are numerous other types of anchor (aside from block and embedding anchors), some combining the properties of embedding and block types (e.g. shaped concrete blocks), whist others are designed for particular types of substrate (e.g. soft mud anchors). For example, the simplest and cheapest type of marine anchor is the dead weight or block anchor which typically consists of a bag of stones or sand or scrap metal or a block of concrete (Beveridge, 1987).

Anchor or mooring lines are either made of natural fibre, synthetic fibre ropes or metal chains. Klust (1983) reported that natural fibre was not particularlysuitable as a mooring line, since it was easily abraded and prone to rotting. Beveridge (1987) noted that steel cable, although immensely strong, was

expensive and heavy and had little elasticity, although it was sometime used for mooring cages to the land. Synthetic ropes are composed of nylon, polyethylene, polyester or polypropylene. However, nylon was much stronger than other ropes on a per unit weight or equivalent diameter basis. Nylon was also more elastic than other materials (Klust, 1983). Klust (1983), in a comparison of three-strand laid ropes of equal diameter, found that at 20% of their breaking load, nylon extended by about 20%, polyethylene by between 7 and 11%, polypropylene by between 6 and 9% and polyester by around 3%. Recovery, once the load was removed was extremely rapid for nylon rope.

As a general guide, the total length of the mooring line to the anchors should be at least three times the maximum depth of water at the site (Torres, Pers. Comm.; Beveridge, 1987). This specified length of the mooring line provides enough slack for water current, tidal fluctuations, wind action, and sudden rise of water depth resulting from heavy flooding.

2.2.5 Rigging Net-cages

Net cages need to be rigged out or distended when put in the water medium so as to provide the maximum of space of the net-cage for fish culture (Alvarez, 1982). The extent and nature of the rigging required depends primarily upon the size

of the cage bag, whether it is to be used in a fixed or floating type, and the design of the collar (Beveridge, 1987). Several methods are employed in rigging net-cages. In Hong Kong, two sets of vertical polyethylene ropes or line connect the upper frame of galvanized iron pipe to the lower one, such that pulling one set of the ropes will lower and distend the net into its shape and the other set of rope will draw up the net-cage (Mok, 1982).

Other methods of rigging cages as described by IDRC/SEAFDEC (1979) and Mok (1982) include the Pulley system which is similar to the Hong Kong method but has rings at the four corners of the frame work along which the ropes are pulled. Another method merely attaches weights in form of stones or concrete blocks at the four corners of the cage (IDRC/SEAFDEC, 1979). Yet another method is used for net-cages with a narrower bottom than the top; a weight such as cement block, bottle filled with sand is attached to each of the four bottom corners of the cage and the cage is fully distended (Alvarez, 1982). At Linwood Acres Trout Farms in Ontario, Canada, Taylor (Pers. Comm.) reported that weights used to hold the shape of the net-cages were usually cement blocks or plastic jugs filled with sand. Re-inforcing bars formed into a square was also experimented on as rigging system (Beveridge, 1987).

2.2.6 Fixed Cages

Fixed cages generally do not need any floatation since they are tied to pillar supports staked into the bottom mud of the water body. These types of cages are often used in shallow waters and therefore do not have a raft (IDRC/SEAFDEC, 1979).

The stakes are either of bamboo poles, wood coated with asphalt or sometimes galvanized iron pipes. In Laguna Lake, bamboo poles are the commonest framework to which the cages are tied. Some other bamboo poles are also tied horizontally to the stakes as additional support and as well as walkway. The poles are tied together with nylon (polyamide) ropes and the cage net is made of either polyethylene or nylon materials (Anonymous, 1979).

2.2.7 Bamboo used in Cage Construction

In those parts of the world where fixed cage is used, bamboo is commonly employed for the supports (Beveridge, 1987). Dela Cruz (1982) observed that among the many species of bamboo available in the Philippines, Bambusa spinosa when matured was the most preferred for framework/raft construction because of its durability and longer life in water.

When compared with other materials on a weight-for-weight basis, bamboo is exceptionally resistant to bending and tension forces but, due to its unique structure, it is much weaker in terms of resistance

to shear forces (Beveridge, 1987). In tests, it was found that once the ultimate bending force was overshot, failure occurred not because the tensile strength of the fibre was exceeded, but because of loss of cohesion between fibres as a result of the materials' low resistance to the shear forces generated (Janssen, 1981).

Despite its many excellent properties, bamboo suffers from one principal disadvantage: it has a comparatively short useful working life. It is susceptible to destruction by boring insects and also eventually becomes waterlogged, thus losing its floating properties (Chong, 1977; Janssen, 1981). The concensus of opinion is that bamboo has a useful working life of around 18 to 24 months in freshwater and 12 to 18 months in seawater (IDRC/SEAFDEC, 1979).

2.3. Size and Shape of Cages

The size and shape of cages depend on various parameters such as prevailing environmental condition in the locality; depth of water; costs and availability of construction materials; fish species to be cultured; local skills and the methods of culture (extensive, semi-intensive or intensive) (Anonymous, 1979). In practice, lack of knowledge of the effects of cage size or shape on fish production and lack of research into the interaction between impinging environmental forces and cage

structures has resulted in cage designs having largely evolved empirically. Hence, until recently it could be said with little fear of contradiction that all cage designs, traditional and other wise, reflect more the limitation of the materials used, local skills and the prevailing socio-economic situation rather than the requirements of the fish or the environmental conditions in which the cage are to be sited. This is not really surprising because the forces acting on a cage and mooring system are exceptionally complex and difficult to quantify, and analysis of the responses of a cage structure to these forces requires the development and use of sophisticated test signs and computer models (Beveridge, 1987). A thorough evaluation of holding facilities for fishes requires not only studies into water quality at different stocking densities but also investigation of the fishes, behavioural and physiological responses (Beveridge, 1987). Research and development work of this nature is expensive and as Kerr (1981) has indicated, is unlikely to be carried out whilst the fish farming industry remains small and fragmented and unable to make a concerted effort to provide funding. Moreover, there has been little incentive to carry out this type of investigative work since most designs work reasonably well, at least in comparative shelter afforded by most coastal and

However, present knowledge as regards cage size and shape is sufficient to provide only the most general of guidelines (Beveridge, 1987). Cages could be circular, rectangular, octagonal or square. But for ease of operation and management, rectangular cages are preferred (Anonymous, 1979). Circular cages were found suitable for the culture of certain (schooling) fish species such as milk fish, yellow-tail and salmon which tend to swim fast and in circles when enclosed (Sutterlin et al., 1979; Yu et al., 1979), and are thus believed to provide a less stressful environment. Beveridge (1987), however, opined that octagonal or square designs probably work equally as well. Other, less active fish species such as common carp and tilapias are thought to be less particular with regard to the shape of the holding facility (cage) (Anonymous, 1979). In the Federal Republic of Germany, rotating globular cages are used in order to overcome the problem of fouling and erosion of nets (Anonymous, 1979).

The influences of surface area and depth of cages on the health and production of fish have been little studied to date (Phillips, 1985). Cages of less than 1.5m depth have been shown to retard growth and change body shape of common carp and tilapia (Maruyama and Ishida, 1976 and 1977),

whilst depths greater than 10 - 12m are probably poorly utilised by most fish species, unless during period of adverse surface temperature or water quality conditions. Cages for holding flat fish such as turbot are an exception. Cage bag depths of between 0.9 and 1.6m are recommended and give the fish sufficient shelter from surface effects, whilst providing an adequate water volume for exercise and feeding (Kerr et al., 1980). However, for effective control it was recommended not to increase the individual unit (cage) size more than 8 x 8m (Anonymous, 1979). For commercial operations, sizes may be larger especially for freshwater cage culture. Bigger cages have been shown to be better suited to larger and faster swimming species such as the tunas (Watsuzato, 1975), although for most species the beneficial effects of large capacity cages on growth and production have yet to be proven. From the fish farmer's point of view, the principal advantage of increasing cage size is that costs per unit volume becomes increasingly cheaper and this is the main reason for the trend in sectors of the industry towards the use of progressively larger rearing units. In Scotland, for example, the traditional 300 - 400m^3 Atlantic salmon rearing cages are being replaced at many farms by cages of at least twice this volume (Beveridge, 1987). The most salient amongst the disadvantages of using larger cages are that the water

exchange is likely to be poorer, since surface area: volume ratio decreases with increasing size and that doubts concerning the use of increasingly large rearing units have been voiced by the insurers who are concerned about the risks involved in holding tens of tonnes of fish in a single cage (Beveridge, 1987).

In spite of the trend towards the use of larger cages, Coche (1976) on the other hand, recommended a cage maximum rearing capacity of $20m^2$. He further stressed that a cage capacity of 5 - $10m^3$ would be preferable for increased manouverability and flexibility. Large cages are more difficult to manouver or manage, requiring two or more staff to perform even the most simple of routine operations. Inspection of nets and removal of mortalities may have to be carried out by divers, whilst monitoring fish health becomes very difficult. Grading of the stocked fish, too, is a problem and for this reason it has been suggested that the new generation of giant cages may be best suited to the culture of species such as yellowtail, which do not require periodic sorting and harvesting (Beveridge, 1987). In Lake Bunot, Philippines, floating cages, each 50 x 25 x 25m depth made of polyethylene netting is common (Guerrero, 1981). A 10 - 20 unit cage farm is recommended for fishermen for management on a

part-time basis (PCCAR, 1980). Various other sizes of cages have been used and reported by several workers. For example, nylon net-cage 4 x 4 x 3.3m deep built to hold 1 metric ton of fish was reported by Landless (1974), while 5 x 5 x 4m deep and 3.5 x 3.5 x 4m deep using synthetic fibre netting was reported in Anonymous (1976). Other sizes of cages used include the knotless nylon net-cage 6.1 x 9.2 x 4.6m deep (Novotny, 1975); nylon net-cage 9.1 x 10.2 x 3m deep (Hunter and Farr, 1970). Other sizes with various other materials used and reported include knotless nylon net-cage 4.6 x 4.6 x 6m deep and 7.6 x 7.6 x 6m deep (Kennedy, 1975a,b); knotless nylon net cage 15.2 x 15.2 x 7.6m deep and 64.1 x 5.5 x 5.5m (Lindbergh, 1971; 1979). Some of the metal-netting type used and reported are Cu-Ni mesh 3 x 6 x 3m deep (Ansuini and Huguenin, 1978); circular galvanized net-mesh cage 8m diameter x 6m deep and 14m diameter x 7m deep (Milne, 1979). The sizes of net-cages used for experimental culture studies varied from 1 x 1 x 1m deep to as large as 4 x 3 x 2m deep in order to have several replicates of each treatment (Guerrero, 1980; Jee, 1980; Galapitage, 1982; Ishak, 1987). For hatchery operation, fine mesh nylon (1 - 3mm) or mosquito net-cages termed hapas are used to breed tilapias (especially the mouth-brooding species). The sizes of the hapas vary from 1 x 1 x 1m deep to 10 x 2 x 1.5m deep for

experimental studies (Guerrero, 1977; 1983). Generally, commercial tilapia hatcheries using hapas are often located in large ponds (i.e. hapa-in-pond hatchery) or bays of reservoirs and lakes (i.e. lake-based hatchery). The sizes of the hapas used in these commercial tilapia hatcheries vary from 3 x 3 x 1m deep to 5 x 5 x 2m deep (SEAFDEC, 1981; 1983; Beveridge, 1984; Behrendts, 1984; Yater and Smith, 1985).

2.4 Culture/Management Practices

2.4.1. Introduction

This aspect of cage fish culture is very important or crucial because the activities carried out during this stage of the enterprise mar or make the best production possible out of the system given the constraints imposed by the site, stock and type of feed used. In order to achieve the best production possible, the caged stock must be kept in conditions which minimize losses and promote good growth and according to Beveridge (1987), this means:-

- stocking the fish at densities appropriate to site, species and methods of rearing;
- feeding the fish in the most cost effective manner;
- ensuring the best possible water quality within the cages;

- maintaining the cages; rigging/mooring system and ancillary structures;
- regular checking of stocks for signs of disease, removal of mortalities, and treatment of infected fish.

In addition, accurate records of water quality conditions, growth and mortalities should be kept so that management procedures can be properly evaluated and modified if necessary.

2.4.2 Fish Species Selection

Most of the fish species cultured in cages are expected to fulfil in part some of the following requirements:-

- breed in captivity thus assuring ready availability of fingerlings;
- grow fast;
- good consumer acceptance;
- adapt to crowding
- high tolerance to a wide range of environmental condition;
- resistance to disease;
- accept natural food or can adapt to artificial food; and
- ease of culture or management.

Tilapia, for example, fulfils all these requirements and it is therefore, not surprising that it is the most widely cultured fish in cages

(Mane, 1979; Alvarez, 1981; Coche, 1982; Guerrero, 1983; Oliva, 1985; Ishak, 1987). There are several other fish species cultured in cages world-wide which definitely fulfil some of the requirements enumerated above (Table 2.1). In freshwater, salmons (Oncorhynchus salmo), trout (Salmo irideus), channel catfish (Ictalurus punctatus) and increasingly, common carp (Cyprinus carpio) are reared intensively in cages, whilst in the marine environment Atlantic salmon (Salmo salar), yellowtail (Seriola quinqueradiata) and serranids (Epinephelus spp) are the main intensively farmed species (Hjul, 1978; Anonymous, 1979). Some intensive rearing of cage tilapia - normally a low value species - is practised in parts of the United States, Southeast Asia (Taiwan, Hong Kong, Japan) and Mexico, where they fetch a high market price (Beveridge, 1987). Mullets and Clarias sp are other fish species of demonstrated potential for culture in cages in freshwater. A glance through the taxonomic index in Coche's bibliography on cage culture reveals that more than 130 fish species and nearly a dozen species of lobster, crab and prawn have been reared in cages, at least, on an experimental basis (Coche, 1983). Bottom-dwelling flat fishes (e.g. Scophthalmus maximus) too, had been successfully cultured in cages fitted with a solid bottom (Hull and Edwards, 1979).

Table 2.1 Commercially Important Fish Species in Use for Cage Fish Farming

Common Name	Scientific Name	References
Tunas	Thunnus thynnus, Euthynnus pelamis	Piccinetti et al. (1980); Butter (1982)
Salmon	Oncorhynchus salmo	Moring and Moring (1975); Kennedy (1978); Sutterlin et al. (1979)
Atlantic salmon	Salmo salar	Glen (1978); Alderson (1984); Giedre (1984); Anonymous (1985)
Trout	Salmo irideus	Muller (1979); Hays (1982); Enell (1982)
Rabbit fish	Siganus sp.	Tugsin (1982); Wong (1982); Yaman (1982)
Serranids or Groupers	Epinephelus spp	Chua and Teng (1980); Wong (1982)
Yellow tail	Seriola quinqueradiata	Milne (1972, 1979); Fajiya (1979); Kuwa (1983, 1984); Nose (1985)
Milk fish	Chanos chanos	Yu et al. (1979)
White fishes	Coregonus spp	Bronisz (1979); Jager and Nellen (1981); Zaugg and Pedroli (1984)
Common Carp	Cyprinus carpio	Muller and Varadi (1980); FAO (1983)
Channel catfish	Ictalurus punctatus	Schmittou (1969); Eley et al. (1972); Kilambi et al. (1976)
Mudfish	Clarias lazera	Ishak (1987); Emeheld and Mbagwena (1986)
Striated snake head	Channa striata	Christensen (1989)
Sea perch	Lates calcarifer	Wong (1982); Yaman (1982)
Tilapia	Oreochromis niloticus	Guerrero (1975, 1979, 1980); Ishak (1987); Campbell (1985)
	Sarotherodon mossambicus	Rifai (1979, 1980); Guerrero (1981)
	Sarotherodon aureus	FAO (1977); ADCP (1978)
	Sarotherodon galilaeus	Ita (1976)
Prawns	Penaeus monodon	Tomiyana (1973); Krishnan et al. (1984); Maheswari (1984); Dela Pena and Prospero (1984)

2.4.3 Fish Seed Production

Because of their smaller size and for the fact that they are easier to manage, cages are more adaptable than pens and can be used not only for grow-out of fish to market size, but also as hatcheries for breeding and fry production of fishes such as the tilapias (Pagan-Font, 1975; Rifai, 1980; Guerrero, 1983; Beveridge, 1984; 1987) and for nursing of the planktivorous juvenile stages of carps, pike and white fish (Bronisz, 1979; Jager and Kiwus, 1980). Hatcheries may be either in-door or out-door using extensive, semi-intensive or intensive methods for production of the fish seed in one type of enclosure or the other like concrete tanks, plastic tanks, fibre glass tanks, net-hapas, concrete raceways, earthen ponds and so on.

2.4.3.1 Tilapia Seed Production

Several methods have been used to produce tilapia seed either at experimental or commercial level. They include the land based methods - open pond and hapa-in-pond hatcheries (Broussard et al., 1983; Beveridge, 1984); lake-based hatcheries using net-hapas (Radan, 1979; Guerrero and Garcia, 1983; Hughes and Behrends, 1983); modular system using plastic-lined swimming pools (Shell, 1966; Snow et al., 1983).

Breeding of tilapia in ponds is the most extensive method. It is applicable where ponds are available and when labour is limited. For example, for a 500m²-pond, 200 females and 50 males (i.e. Male:Female, 1:4) are needed (5,000 breeders/ha). Well managed breeding ponds can yield up to 100 fingerlings/m² in four months (Anonymous, 1982).

Rice paddy field had also been modified to produce tilapia fingerlings. Breeders were stocked in paddies at the rate of one per four square metres (2,500/ha) and with a sex ratio of one male to four females (i.e. 50 breeders consisting of 40 females and 10 males in a 200m² paddy). Fingerlings were collected after two months of culture. Guerrero (1982) recorded a yield as much as 50 fingerlings/m² in two months.

In the hapa-in-pond method, breeders are stocked in small net-hapas (3 x 3 x 1m, 1 - 3mm mesh). The hapas are attached to wooden stakes driven into the substrate, so that the bottom remains 10 - 20cm above the pond bottom. They are stocked with broodstock fish at densities of 4 - 7/m² at ratios of 3, 5 or 7 females to each male (Beveridge, 1987). The stocked fish rely on natural production and/or supplementary feed. The fry are removed at regular intervals by concentrating them in a corner of the enclosure and

then scooping them out with a small-meshed net. They may then be transferred to nursery hapas and kept till sold (Beveridge, 1984). Using a good quality locally-compounded feed (e.g. 25% fish meal, 75% rice bran), production rates of 240 fry/m²/month can be achieved in land-based systems. This is at least an order of magnitude greater than production typically achieved in small backyard operations where less feeding is likely to occur and where broodstock and management techniques are often poor (Beveridge, 1984; Yater and Smith, 1985). Using twelve breeding net-enclosures, each measuring 4 x 12 x 2.5m stocked with 80 breeders, that is, 4 breeders/m² at 1:3 male to female ratio, De la Cruz (1982) reported a production of 200,000 fry in 2 spawnings or 3 months (i.e. 1,389 fry/m²/month). Under experimental conditions, Hughes and Behrends (1983) have achieved in excess of 2,000 fry/m²/month with the hapa-in-pond method in the USA (stocking density, 5 breeders/m², ratio of 2 females to 1 male).

Since the late 1970s and early 1980s, research scientists of Southeast Asian Fisheries Development Centre (SEAFDEC), Laguna Lake Development Authority (LLDA), and various Universities experimented with lake-based hatcheries and nurseries with the result that today, there are several commercial lake-based fry and fingerlings units in operation particularly on Laguna Lake in Southern Luzon and in the San

Pablo Lakes. Most operators use large net-hapas (typically 5 x 5 x2m) attached to bamboo wooden poles driven into the lake substrate. These are stocked with broodstock and managed in a similar way to hapa-in-pond method. From trials carried out by SEAFDEC staff, the optimum stocking densities of 2.5 - 5.0 broodstock/m^4 at ratio of 5 - 7 females per male gave the highest fry production per unit cage area (SEAFDEC, 1981; 1983) although more recent work suggest 2 or 3 females per male should be used (Beveridge, 1987). A number of modified designs have also been developed to improve fry production by minimising cannibalism of young fry by older fry and broodstock (Beveridge, 1984; Guerrero and Garcia, 1983). In the first modified design (Figure 2.1b), the broodstock are confined to a large mesh (30mm) net-enclosure within the hapa net bag, so that the fry produced in the large mesh enclosure easily pass through to the hapa net bag (Figure 2.1). However, the flow of water through the outer hapa to the confined broodstock net-cage may be restricted by biofouling by epiphytic algae and detritus; since the broodstock do not have access to the wall of the outer hapa and therefore cannot graze. An alternative design was proposed by Bautista (1984) of SEAFDEC, Binangonan, Philippines (Figure 2.1c) in which good flow conditions to the broodstock are ensured.

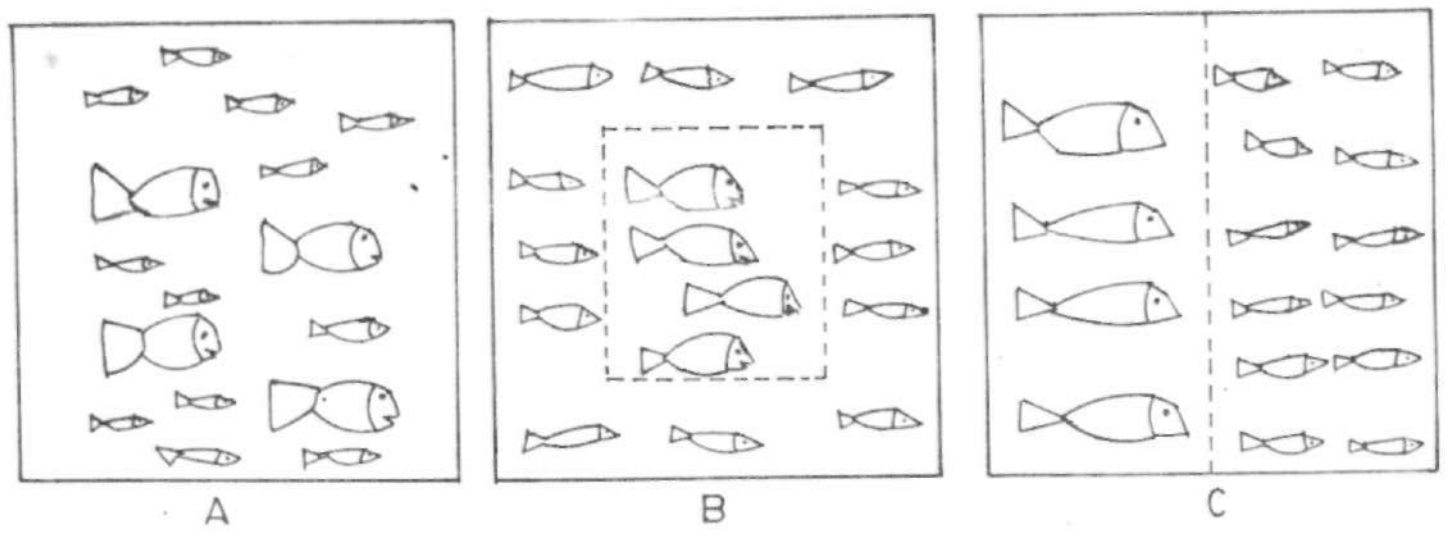


Fig. 2-1 Designs for Lake Based Tilapia Hatcheries (A) simple Hapa. (B) Broodstock restrained in central area of Hapa. (C) Broodstock restrained in One half of the Hapa (modified from Beveridge, 1984)

Trials conducted by Guerrero and Garcia (1983) comparing the designs shown in Figures 2.1a and b concluded that although there were significant differences in fry production per unit area, production per breeder was greatly increased, although the cost of the modified design offset this disadvantage.

Hughes and Behrends (1983) working on mass production of Tilapia nilotica seed in suspended net-enclosures concluded that the hapa system for T. nilotica appears to be more productive than most other systems. Fry production of less than 0.4/m² per day were reported in earthen ponds (Coche, 1982) and 8/m² per day in tanks (Berrios-Hernandez, 1979). Only in cages and hapas (30 fry/m² per day) (Coche, 1982) did production approach that of fry production in the study (29 fry/m² per day from a maximum of 73 seed/m² per day).

2.4.3.2 Seed production of some other fish species

The main sources of milkfish (Chanos chanos Forskal) supply are the brackish water nurseries where the fry collected from the wild are reared to fingerling size (IDRC/SEAFDEC, 1983). Eventhough, some success have been attained in the induced spawning of milk fish breeders in captivity but the hatchery management are yet to be refined.

The seed for carp are obtained from gonadotropin induced breeding. 260 million carp seeds were produced in India in 1978-1979 from induced breeding (Davy and Chouinard, 1980). On the other hand, a semi-controlled breeding method entails the use of breeding hapas similar to those used in Tilapia hapa-in-pond or water-based hatcheries. Egg collectors referred to as kakabas are usually dropped inside the hapas. The gravid females are placed in the hapas with mature males at a ratio of one female to two males (and a density of three breeders/m^3 hapa). Spawning normally takes place and the spawners are quickly removed to prevent cannibalism. The hatchlings after absorbing their egg yolk are then reared to fingerling subsisting on proper feeding.

In most developing countries, a reasonable percentage of Clarias sp fingerlings used for stocking aquaculture systems including cages are often obtained from the wild or natural sources (Viveen et al., 1986). The supply from these sources are often inadequate (in quality and quantity), seasonal and the collection may result in depletion of the natural stocks and disturbance if not destruction of the ecosystem. The most promising source is therefore, the artificial propagation through induced breeding by use of

pituitary extract (hypophysation) or by the use of artificial gonadotropin or human chorionic gonadotropin, HCG (Trade Name:- Primogonyl) (Madu et al., 1987). The fertilized eggs after incubation hatch to produce the hatchlings which are reared up to fingerlings stage before stocking in the grow-out system.

2.4.4. Hybridization

2.4.4.1 Introduction

The motives behind hybridization in fishes is a search for improved qualities like higher growth rate, feed conversion efficiency, survival, meat quality and the adjustment of age at first maturation (Chevassus and Coche, 1986).

For the past 10 years, the Israeli fish culturists have worked on the hybridization of Tilapia in order to produce all male populations for the fish farmers' commercial use.

Hybridization within certain families of tropical fishes is not uncommon. Hybrids have been observed in some groups of fishes e.g. the Cyprinidae (carps), Centrarchidae (sun-fishes) and Esocidae (pikes) (Chevassus and Coche, 1986). In nature, hybridization may be produced accidentally and they are much more common among freshwater fishes than among seawater species. However, as the stimulus of a ripe male

appears to be necessary in some species to induce the females to release eggs, the possibility seems remote that sperms from outside source might fertilize the eggs thus released. However, there are recorded instances of female carp releasing ripe eggs without the stimulus of a male fish (Huner and Dupree, 1984).

2.4.4.2 Natural hybridization

Hybrid fish are not rare in nature. Slastenenko (1957) lists 212 known hybrids belonging to 23 families of which 91 are between cyprinid. Hubbs (1955) has shown that, in suitable conditions the rate of natural hybridization may be high. For example, where two allied species of fish more or less share the same spawning ground, but where one of the species is more abundant than the other, hybridization may occur because individuals of the less abundant species having difficulty in finding males of their own species. In such conditions, Hubbs (1955) found up to 90% hybrids among Lepomis in a Michigan stream. In fish culture, where a male and a female of different species can be isolated in a pond, breeding will often take place. So it is with several species of Tilapia, even inter-generic cross may be made in such conditions, as with members of the sturgeon family Acipenser and Huso.

2.4.4.3 Intra-specific Hybridization

A note worthy recent example, is the improvement of the common carp, Cyprinus carpio, by crossing cultivated common carp with wild carp from the river Amno. The common carp has been cultivated for many centuries in Europe, and European stocks have become very inbred (Scheperclaus, 1959). Crossing with the wild stock produced a cross called the kursk carp which is known to have a greater resistance to cold temperatures than the cultivated carp. Hence, the kursk carp makes fish culture possible in the colder, more northerly latitudes.

2.4.4.4 Inter-specific hybridization

A large number of hybrids between Tilapia spp and between Sarotherodon spp as well as intergenetic hybrids between Tilapia spp and Sarotherodon spp have been formed in the wild or produced intentionally. A list of almost 30 hybrids drawn from summaries of successful interspecific hybridization from Elder et al., (1971) and Balarin (1979) is shown in Table 2.2. Thus, success of interspecific crosses tend to be more readily reported than failures, though the latter may also be of interest. Table 2.3 gives a summary of attempts at hybridization which did not result in viable offspring. In some cases, the same interspecific cross appears in both Tables 2.2 and 2.3. This is due to success in one

Table 2.2 Hybrids between different tilapias (Figures refer to list of sources below)

Breeding type	Species[a]	Observation in nature	Deliberate crosses carried out		Sex of hybrid progeny in deliberate crosses
			In ponds or tanks	Under Lab. conditions	
Maternal mouth-brooder X Maternal mouth-brooder	S. niloticus x S. spilurus niger	17	21		Surplus of males.
	S. niloticus x S. macrochir		3,12,15		Only males when S. niloticus female parent.
	S. niloticus x S. aureus		9,14,21,22,30		Occasionally males only when S. niloticus female parent.
	S. niloticus x S. variabilis	25,26	21		Only males when S. niloticus female parent.
	S. niloticus x S. leucostictus		21		Surplus of males.
	S. niloticus x S. hornorum		14,16,21		Only males when S. niloticus female parent.
	S. niloticus x S. mossambicus		6,13,24,30		Surplus of males.
	S. mossambicus x S. hornorum		5,10		Only males when S. mossambicus female parent.
	S. mossambicus x S. andersonii	18			
	S. mossambicus x S. spilurus niger		29		Surplus of males.
	S. mossambicus x S. aureus		2,30,31		Surplus of males (S. aureus misidentified as S.niloticus).
	S. vulcani x S. hornorum		21		Large surplus of males.
	S. spilurus niger x S. hornorum		21		Only males when S. spilurus niger female parent.
	S. spilurus niger x S. leucostictus	7,8	21		Surplus of males.
	S. amipheles x S. esculentus	23			
	S. vulcani x S. aureus		22		Large surplus of males.
	S. hornorum x S. aureus		14,21		Surplus of males.
Maternal mouth-brooder X Paternal mouth-brooder	S. melanotheron[b] x S. Mossambicus			4,19	Only females when S. melanotheron female parent.
	S. melanotheron[b] x S. niloticus			4,19	

Table 2.2. (contd.)

Breeding type	Species[a]	Observation in nature	Deliberate crosses carried out		Sex of hybrid progeny in deliberate crosses
			In ponds or tanks	Under lab. conditions	
Maternal mouth-brooder X Substrate breeder	T. tholloni x S. mossambicus			4,19,20	Only females when T. tholloni female parent.
	T. tholloni x S. niloticus			4,19	Only females when T. tholloni female parent.
	T. zillii x S. mossambicus			4	
	T. zillii x S. spilurus niger	28	11		Only males. Sex of parents not given.
Paternal mouth-brooder X Substrate breeder	T. tholloni x S. melanotheron[b]			4,19	
Substrate breeder X Substrate breeder	T. zillii x T. rendalli[c]	26,27	1		Sex ratio 1 : 1

Sources:

1. Anon. (1962). 2 Avault and Shell (1967). 3 Bard (1966). 4 Bauer (1968). 5 Chen (1969). 6 Chen (1976). 7 Elder and Garrod (1961). 8 Elder et al. (1971). 9 Fishelson (1962). 10 Hickling (1960). 11 Ibrahim (1975). 12 Jalabert et al. (1971). 13 Kuo (1969). 14 Lee (1979). 15 Lessent (1968). 16 Lovshin and Da Silva (1975). 17 Lowe McConnell (1958). 18 Mortimer (1960). 19 Peters (1963). 20 Peters and Brestowsky (1961). 21 Pruginin (1967). 22 Pruginin et al. (1975). 23 Trewavas and Fryer (1965). 24 Van Schoor (1966). 25 Welcomme (1964). 26 Welcomme (1965). 27 Welcomme (1966). 28 Whitehead (1960). 29 Whitehead (1962). 30 Hsiao (1980). 31 Pierce (1980).

[a] Order of species does not indicate sex of parents, either because original source failed to give it, or to save space when both reciprocals have been produced.

[b] S. macrocephalus.

[c] S. melanopleura.

Table 2.3 Documented unsuccessful attempts at tilapia hybridization

Breeding Type	Parents		Reason for failure of hybridization	Sources
	Female	Male		
Maternal x Paternal mouthbrooder	S. mossambicus	S. melanotheron[a]	No fry obtained	Bauer (1968) Peters (1963).
Maternal mouthbrooder x Substrate breeder	S. niloticus	T. tholloni	High fry mortality	Peters (1963) Bauer (1968).
	S. mossambicus	T. tholloni	High fry mortality	Peters (1963) Bauer (1968).
	S. aureus	T. zillii	No fry obtained	Van Schoor (1966). Hsiao (1980).
	T. zillii	S. aureus	No fry obtained	Van Schoor (1966)
Paternal mouthbrooder x Substrate breeder	S. melanotheron[a]	T. tholloni	High fry mortality	Peters (1963) Bauer (1968).
Substrate breeder x Substrate breeder	T. sparrmanii	T. zillii	No fry obtained	Van Schoor (1966).
			No fry obtained	Van Schoor (1966).
Substrate breeder x Biparental mouthbrooder	T. zillii	S. galilaeus	No fry obtained	Van Schoor (1966).

a = S. macrocephalus

reciprocal cross but failure in producing in the other (Wohlfarth and Hulata, 1981).

Most successfully produced hybrids (Table 2.2) are between different species of maternal mouth brooders. This is expected because the vast majority of tilapia species belong to this breeding type. However, most of the other combinations between different breeding types are represented by at least one hybrid (Wohlfarth and Hulata, 1981).

2.4.4.5 Tilapia crosses which produced 90 - 100% male hybrids

Hickling (1960) obtained all male broods from the cross of Tilapia hornorum male x T. mossambicus female. Pruginin (1967) carried out a series of crosses between different species of Tilapia and obtained the following results of all-male hybrids:-

T. leucosticus (M) x T. niloticus (F) = 94%
T. leucosticus (M) x T. nigra (F) = 95%
T. variabilis (M) x T. niloticus (F) = 100%
T. hornorum (M) x T. nigra (F) = 100%

(M) = Male; (F) = Female.

Jalabert et al. (1971) working at a station in Bouake, Ivory Coast crossed T. macrochir (M) x T. niloticus (F) and obtained 100% males. Fishelson (1962) crossed T. niloticus (F) with T. aureus (M) and obtained all male progeny. Pruginin et al. (1975) obtained the same results at the Fish and Aquaculture Research Station at Dor, Israel.

2.4.4.6 Selective breeding, hybridization and genetic engineering

Selection, hybridization and genetic engineering are crucial to the improvement and development of aquaculture. Genetic manipulations in fin fish and shell fish are aimed at the same goal as selection, cross breeding or hybridization - that is: the genetic improvement of commercial performances. Chevassus and Coche (1986) observed that despite some preliminary attempts with self fertilization or gene transfer, the genetic manipulations essentially consist of modification of the chromosome set as gynogenesis, androgenesis, auto- and allo-polyploidy. Chevassus and Coche (1986) reviewing the case studies of large-scale breeding programmes noted that the practical application of genetic manipulations breeding plans to commercial fish farming was restricted to channel catfish culture in USA, common carp farming in Israel and Hungary, and Salmonid culture in Norway.

2.4.5 Stocking density and production in cage

The stocking density of fish in cages varies according to the fish species and size and the level of management anticipated. To some extent, the stocking density is a function of the fish production.

In Japan, carp fingerlings are stocked at rates of 10 to 80/m^2 and when heavily fed, carp production may reach 4,000 kg/ha (Bardach et al., 1972). In German

Democratic Republic, common carp were stocked at the rates of 200, 400 and 600 per m^3 in different cages and were fed during the first two months eight times and later six times a day with a 33.7% crude protein pelleted feed. The best and highest weight gain was achieved at 200/m^3 stocking density. The carp grew from initial weight of 50 g to 268 g in 93 days culture period (Muller, 1979). In former USSR, Miheev et al. (1971), found a stocking density of 800, 1g rainbow trout/m^3 of floating cage as optimum. In Malaysia, Teng and Chua (1979) showed that stocking density of estuary grouper in floating net-cages could be increased from the optimal stocking rate of 60 fish/m^3 to 156 fish/m^3 by providing artificial shelter using old car tyres They found net fish production to increase by 260%. In the Philippines, Tilapia mossambica cultured in commercial cages in Lake Bunot (a slightly oligotrophic lake) was stocked at densities as high as 100,000 fingerlings per cage or 16 fingerlings/m^3. The average weight of the fingerlings was 5 - 10 g. The fish production was 10 - 15 tons per cage after six months of culture (Guerrero, 1979). In Laguna Lake, Tilapia nilotica stocked at 50 fingerlings (2g average weight)/m^3 may reach a marketable size of 100 - 150g in 4 - 5 months (Basiao, 1980). Coche (1982) in a detailed review of cage culture of Tilapia observed that under semi-intensive cage culture of tilapias using mixed feeds and at stocking rates varying from 22 to 100 fish/

m^3, a monthly fish production range of 0.06 to 3.87kg/m^3 was obtained. Cocne (1982) also observed from various countries that under the intensive cage culture of S. niloticus including monosex male populations at a stocking density range of 7 to 600 fish/m^3, the fish harvest ranged from 2.5 to 18.3kg/m^3 per month.

In yellow tail culture, the stocking density depends on the size of the fish, and the prevailing environmental conditions. Recommended stocking densities, based on average conditions vary from 10 - 90 fish/m^3 for a size range of 1,000 g to 10 g fish respectively such that the stocking densities varied between 10 to 0.9kg/m^3 i.e. stocking density increases from a minimum of 0.9kg/m^3 when the fingerlings are first stocked in the grow-out cages at an average weight of 10g each, to a maximum of 11kg/m^3 when the fish reach 500g (Fujiya, 1979). But under ideal conditions, stocking densities of up to 20kg/m^3 can be achieved (Kafuku and Ikenoue, 1983). FAO (1979) reported that for yellow tail seed size 5 - 10 cm in total length, the standard stocking density was 80 - 200 fish/m^2 in floating cages. At harvest, the average weight of fish was 1.0 - 1.5 kg after eight months of culture. However, in recent times, the tendency is to keep stocking levels as low as possible (Nose, 1985). In India, under experimental cage culture of Penaeus monodon, at stocking densities of 1 to 15 (average size 0.3g to 2.5g) juveniles per m^2, the

production ranged between 0.01 to 0.09 kg/m² per month (Maheswari, 1984; Krishnan et al., 1984).

In cage culture, monoculture is the rule and polyculture the exception (Beveridge, 1987). However, some polyculture of carps in cages is practised in China, with yields of up to 7.5 kg/m³ per year from extensive systems and up to 13.5 kg/m³ from semi-intensively managed cages (FAO, 1983). Experimental polyculture of Chinese carps in cages has also been attempted in Hungary (Muller and Varadi, 1980).

2.4.6 Feeds and feeding practices

2.4.6.1 Types of Feed

Different types of feeds and feeding practices are in use in cage culture. The practices involved are determined by the fish species and biomass, weather conditions, the stocking density, the level of management anticipated and the production targets (Anonymous, 1979). For example, extensive methods of cage fish farming rely solely on natural food, though, illumination may be used to attract food organisms towards the captive fish (Uryn, 1979; Jager and Nellen, 1981; Mamcarz and Szczerbowski, 1984). Semi-intensive and intensive feeding practices, however, involve supplemental feeding and complete feeding respectively. The supplemental feed used in

semi-intensive operations is usually relatively poor in protein (less than 10% dry weight) and made from local materials readily available at low cost (Coche, 1982). Intensive feeds differ from semi-intensive feeds in that they must supply all the cultured species nutritional requirements, including the right quantities and qualities of proteins, fats, carbohydrates, minerals and vitamins (Halver and Tiews, 1979; NRC, 1981, 1983; Jauncey and Ross, 1982). According to ADCP (1983), feed represents 40 - 60% of the total operating costs in intensive aquaculture.

The use of simple diets, either single ingredient or formulated out of locally-available sources, is practised in many developing countries; whereas the trend in more advanced societies, is towards the use of pelleted feeds (IDRC/SEAFDEC, 1979). Castillon (1982) in the cage culture of rabbit fish, Siganus sp initially used marine algae, Enteromorpha sp and Rhizodonium sp, but three months later, used a supplemental feed consisting of 1% dried ipil-ipil leaves (Leucaena leucocephala), 2% corn or rice bran, and other feedstuffs. Whereas in feeding rabbit-fish in cages, Gargantiel (1982) used fish pellet first soaked in water before feeding to the fish. Aside from fish pellets, he also gave green algae from fish ponds as additional feed for siganids in cages. In Thailand, trash fish cut into pieces and given once a day at about 10% of total body weight is

used for cage culture of seabass (Lates calcarifer) (Tanomkiat, 1982). In India, Natarajan et al. (1979) used a pelleted feed of 32.9% crude protein made up of soyabean powder, groundnut oil cake and rice polish mixed in 1:1:1 ratio in the cage culture of carp. In Indonesia, Reksalegora (1979) used supplemental feed consisting of materials of vegetable origin such as waste of coconut, cassava, leaves of cassava and rubber leaves in the cage culture of the cyprinid, Leptobarbus hoeveni. He also included trash fish in the diet. Also in Indonesia, Rifai (1979) feeding three kinds of aquatic plants namely Hydrilla verticillata, Lemna minor, and Chara sp. singly to Tilapia nilotica in floating cages, observed that Lemna minor gave the best growth rate of the fish in every level of the stocking density. In Malaysia, Chua (1979) reported that the popularly used method of farming estuary grouper, Epinephelus salmoides is stocking 60 fish/m^3 and reared over a period of eight months feeding exclusively on trash fish. In Nepal Sharma (1979) used varying combirations of wheat flour, rice bran, mustard oil cake, cow dung and duck litter as feeds in the cage culture of carp. He noted that there was no objection from the local people to the use of cow dung or duck litter in the feed. In the Philippines, Guerrero (1979) reported the commercial cage culture of Tilapia mossambica in Lake Bunot where the fish subsisted mainly on the

natural food in the lake. He also noted that rice bran was occasionally given as supplementary feed. In Thailand, Tangtrongpiros (1979) in the cage culture of Pangasius sutchi fed pellets made up of 30% ground fish meal, 25% soyabean, 25% peanut, and 20% rice bran at a daily ration of 5% of their body weight to obtain 798g per fish in ten months. In Egypt, Ishak and Hassanen (1987) used experimental diets with crude protein levels of 26, 29 and 32% made up of varying combinations of fish meal, meat, poultry bye-product meal, cotton seed meal, rice bran and wheat bran in the cage culture of Oreochromis niloticus. They observed that protein and energy retention showed a better yield for the fish receiving less protein and that the least cost of production was obtained using the diet containing 26% crude protein. In Turkey, Erden (1987) in the cage culture of mirror carp, used a 31% crude protein feed consisting of 23% wheat bran, 50% sun-flower oil cake, 24% fish meal, and 3% molasses with 0.25% vitamins and 0.1% minerals. In Sri Lanka, Muthukumarana and Weerakoon (1987) in the cage culture of O. niloticus used experimental diets with crude protein of 17% to 29% made up of varying combinations of fish meal, chick mash, rice bran and Shark liver oil. In Niger Republic, Ali (1987) in Tilapia cage culture experiments used a feed consisting of 40% groundnut cake, 40% rice bran, and 20% fish meal.

Coche (1982) gave a very detailed review on the use of aquatic and terrestrial plants, mixed feeds commercial fish feeds and artisanal feeds in the cage culture of Tilapia. Under semi-intensive cage culture of tilapias various aquatic and terrestrial plants like fresh algae, Hydrilla verticillata, Chara sp, Lemna minor and Alocasia macrorhiza leaves were used (Corredor, 1978; McLarney, 1978; Popma, 1978; Philippart et al., 1979; Rifai, 1979, 1980). Under some other semi-intensive cage culture of tilapias, mixed feeds were used: rice bran in the presence of algal blooms (Anonymous, 1979); 70% rice bran, 30% chopped snails in the presence of algal blooms (Pantastico and Baldia, 1979); Alocasia leaves added to 0.5 to 1.0 kg wheat bran (McLarney, 1978); 99% brewery waste and 1% fish meal (Ibrahim et al., 1975). Some artisanal feeds have been found satisfactory for the cage culture of tilapias under various local conditions (Coche, 1982). Their composition is largely based on relatively cheap materials, such as rice polishings, wheat middlings, peanut oil cake, oyster shell, rice bran and cotton seed oil cake, enriched with either fish meal or blood meal (Campbell, 1978; Guerrero, 1979; N'Zimasse, 1979). Coche (1982) reported that researchers have used commercial fish feeds or self-made compounded feeds in fish cage culture. The commercial fish feeds have a very high protein level (e.g. Purina Trout, Chow, 40%; Trouvit, 46%), a balanced composition including essential

minerals and vitamins (at least for the target fish species), and a high price. He noted that self-made feeds, however, have used mixtures of locally available ingredients, giving lower protein levels (usually 20 to 30%) and lower costs. Coche (1982) finally concluded that several empirical feed formulations have been evaluated but none has been developed from scientific data.

7.4.6.2 Feeding practices

At most intensive and semi-intensive cage farms, fish are fed throughout the year, except during periods of adverse weather (Beveridge, 1987). In the former USSR, cages of common carp are over-wintered below the ice surface and are not fed until the spring, when the ice melts and the cages are lifted (Martyshev, 1983), whilst in Western Europe, feeding of Atlantic salmon may be temporarily halted if the temperature rises above 18°C (Langdon, 1985). In Japan, cages of yellow tail are sometimes lowered below the sea surface during typhoons, and whilst some cages are adapted so that feeding may continue during periods of submersion, others are not (Fujiya, 1979).

Most cage farms using supplementary feeds, trash fish or moist feeds, feed their fish by hand, since it is cheaper and easier to do so, at least on a small scale (Beveridge, 1987). Research in Japan suggests that there may be some advantages to feeding

frozen trash fish to caged stock, in that bacterial infections and water pollution are reduced (Taniguchi, 1983). Moist balls of feed which are sometimes used in semi-intensive cage culture of tilapia: may be conveniently fed to the fish by placing them on the top net of the cage and gently lowering the net into the water (Coche, 1982).

Mechanical feeders have largely superseded hand feeding at most large intensive cage farms in recent years, for reasons of economy of labour (Beveridge, 1987). There are two basic types - demand feeders and automatic feeders and the designs used on cages are virtually identical to those used at land-based sites. Demand feeders are cheapest and make food available to the fish round the clock so that they can feed whenever they wish. The relative merits of using demand feeders have been reviewed by a number of authors (Avault, 1981; Boydston and Patterson, 1982) and proponents claim less size variability in stock at harvest, better FCRs, higher production, improved water quality and less disease problems. Automatic feeders differ from demand feeders in that a measured ration is delivered at fixed intervals which are preset by the farmer using some sort of timing device (Beveridge, 1987). Dry pellet automatic feeders are perhaps the most common type installed at cage fish farms, and typically consist of a plastic feed hopper

surmounting a device which releases or fires a quantity of pellets each time it is activated, and are usually operated either by rechargeable batteries or by compressed air. Results from cage culture suggest that at exposed sites, water currents or waves may be sufficient to trigger the pendulum (of the demand feeder) frequently, releasing more food than the fish can cope with (Pitt et al., 1977). However Coche (1977) and Balarin and Haller (1982) report that in several parts of the world this apparent set back has been turned to an advantage in tilapia cage culture, by loading hoppers with small quantities of food only, which when triggered by waves, release the ration continually over a period of several hours.

Electrically powered systems either consist of a centralised power supply with control unit linked to a number of feeders, or have feeders which operate independently and which contain their own power source and control device (Beveridge, 1987).

One criticism concerning the feeding of caged fish is that there has been little study of feeding behaviour and there have been few mechanical feeders designed specifically with caged fish in mind (Phillips, 1985). Goddard and Scott (1980) speculated that due to the relatively small surface area to volume ratio of cages, compared with ponds or raceways, caged surface - feeding fishes should be fed over longer

periods of time at each feed. Also, little attention has been paid to the distribution of feed - either in land-based or water-based systems.

A number of studies have been carried out into the use of feeding tubes, rings, trays or net curtains to reduce feed losses. Coche (1979), for example, has expressed concern that small trays which only partially cover the cage area will, benefit only the more aggressive fishes, whilst Ibrahim et al. (1975) observed that trays provide an unwanted spawning substrate for tilapias. On the other hand, in carp polyculture in cages, it was observed that use of feeding trays lowered to various depth (in the cage) according to the feeding habits of the species seemed to result in efficient consumption of supplementary feed (Anonymous, 1979).

The relative advantages and disadvantages of these various types of feeders are summarised in Table 2.4.

2.4.6.3 Feeding rates

Hand feeding and demand feeders work on the principle that the fish know best when they have had enough, and whilst there is a great deal of truth in this, fish can also overfeed, and it is therefore best to also take cognisance of feed manufacturer's guidelines (Beveridge, 1987). The feeding rate is usually quantified as the daily feed ration, the

Tabel 2.4 A summary of feeding methods at cage fish farms (from Beveridge, 1987)

Type of Feeding	Type of Feed	Usage	Advantages	Disadvantages
Hand-feeding	All types of supplementary and intensive feeds	Used in semi-intensive culture and preferred method at many intensively managed farms, including most yellowtail farms in Japan	No capital expenditure on feeders. Enables monitoring of fish health. Fish can be fed according to appetite. Can distribute feed widely	Can be expensive in man hours at large farms. Ties farmer to farm. Under some circumstances may lead to over feeding Poor FCR values, and high waste loadings.
Demand feeder	Pelleted dry feeds	Used for semi-intensive and intensive culture a range of species	Cheaper then automatic feeders and less labour-intensive than hand-feeding. Feeding rates can be adjusted to suit conditions	Care must be taken to avoid over feeding. Small fish (< 10 g) can't use most designs. Waves can trigger some feeders at exposed sites. May not be suitable for some species. Poor feed distribution pattern.
Automatic feeders:				
a) Air-operated	Pelleted dry feeds	Used for intensive culture of salmonids. Not commonly used on cages.	Farmer can set feeding rate and duration. Relatively good feed distribution. Less labour-intensive than hand-feeding.	Noisy; can be problems in sub-zero condition where icing of valves can occur. Not suited to all cage sites. No feed back from fish to farmer, hence risk of over-feeding

Table 2.4 (contd.)

Type of Feeding	Type of Feed	Usage	Advantages	Disadvantages
b) Electrically operated	Pelleted dry feed	Widely used for intensive fish culture	Farmer can set feeding rate and duration. Less labour-intensive than hand-feeding	No feedback from fish to farmer, hence risk of over-feeding
c) Water powered	Pelleted dry or wet feeds	Used mainly in Scandinavia with wet [illegible]	Computerised system responsive to environmental changes. [illegible] reduced solids loadings. Flexibility in range of feed types used. Computerised comprehensive records	May be problems with vitamin losses. Very expensive to install

amount of feed (wet or dry) being fed daily (generally six days a week) to the fish, expressed as a percentage of the best available estimate of the fish biomass (%B) (Coche, 1982). Such estimates, based on cage sampling, are usually made every 15 to 30 days. In literature, an array of feeding rates have been experimented and used and certain guidelines as to how much feed to give depending on the fish species age/size of the fish, the culture system, the environmental conditions, the quality of the feed and several other factors like the peaks of feeding activity of the fish, fish health are recommended (Martshev, 1983). For example, carnivorous fish species such as catfishes, grouper and salmonids have well-developed stomachs which can store food, and experiments with rainbow trout under constant lighting conditions have shown that at 18°C there are well-defined peaks of feeding acitivity every 6 hours (Grove et al., 1978) but that at the 15°C this rhythm changes to peaks every 8 hours (Adron et al., 1973). Tilapias and carps, on the other hand, which have poorly-developed stomachs or no stomachs at all, require smaller, more frequent meals (Ross and Jauncey, 1981). Goddard and Scott (1980) observed that if fish are fed to satiation with artificial food which is much higher in terms of protein and lipid content, then incomplete digestion will occur, resulting in poor Food Conversion Ratios (FCRs) and increased waste production.

During winter, trout (10 - 15g each) kept in special cages are fed with a vitamin - enriched diet at a rate of 1% body weight, twice per week (Martyshev, 198:). During May and June, the fry of yellowtail are reared in small to large (2 - 50m² in area, 1 - 3m in depth), fine, synthetic-fibre mesh net-cages, which are prone to fouling and must be checked regularly. During this 4 - 6 week period they are fed on available minced fish (anchovy, horse mackerel, saury, sand eel) and shrimp, although according to Fujiya (1979), mortalities are minimized if low-fat, white-fleshed fish is used. Feeding rates during this period are 50% body weight per day (Brown, 1983). In yellowtail growout cage systems, feeding is carried out once or twice per day, although care must be taken not to over feed (Beveridge, 1987). Fish (yellowtail) are fed to 80% satiation level (Fujiya, 1979) and the feeding rate during the first year of growth decreases from 40% body weight per day when stocked in July, to 4 - 5% in January. During this period the water temperature decreases thus reducing feed intake (Sakamoto et al., 1979). As temperature increases during July and August of the second year of growth, appetite improves, growth accelerates and the feeding rate increases to about 8% body weight per day. In tilapia cage culture in the Philippines, several cheap but good compounded feeds have been developed,

the most widely used consisting of 77% rice bran and 23% fish meal (Pantastico and Baldia, 1979; Guerrero, 1980). Recommended feeding rates with this feed are 3 - 5% body weight per day, depending on fish size, the feed being either broadcast on the water surface or moistened into balls and fed to the fish several times per day. However, recent surveys investigated by Philippine Council for Agriculture and Resources Research and Development (PCARRD) and International Center for Living Aquatic Resources Management (ICLARM) have shown that most farmers, especially the poorer ones, feed their fish as and when they can afford (Smith et al., 1985). A number of trials involving the cage rearing of Penaeus monodon juveniles were carried out in Tamil Nadu, India and the feeding rates used ranged from 5 to 50% of their body weight (Krishnan et al., 1984; Maheswari, 1984). In the case of diseased fish, Roberts and Shepherd (1986) recommended that the feeding rate for medicated diets is reduced by about 0.5% below the normal feeding rate. Thus if fish are feeding at 3% body weight per day when they become diseased, the feeding rate with a medicated diet is 2.5% body weight per day. Details of drug incorporation rates are given by Wood (1974), Hoffman and Meyer (1974), Poupard (1978), Stevenson (1980), IDRC (1983), Roberts and Shepherd (1986).

In Hungary, common carp in cage culture were fed two times per day at the rate of 2 - 5% of the body weight (Muller, 1979). In India, during the cage rearing of carp hatchlings, the feed was dispensed in cages in powdered form at 30% of the body weight for 3 - 4 days and subsequently to 20% (Natarajan et al., 1979). In Indonesia, Rifai (1979) fed aquatic plants to Tilapia nilotica in cages at the rate of at least 30% of the biomass. In Thailand, the catfish (Pangasius sutchi) raised in cages were fed pelleted feed at the rate of 5% of their body weight (Tangtrongpiros, 1979). But trash fish fed to sea bass (Lates calcarifer) in cages was at the rate of 10% of the body weight (Dhebtaranon et al., 1979). In Egypt, Ishak (1975) fed tilapia (Oreochromis niloticus and Sarotherodon galilaeus) in cages twice daily, six days a week, at a rate of 5% of the body weight. Under the semi-intensive cage culture of tilapias using aquatic and terrestrial plants, the daily feeding rate ranged from 4.8 to 30% of the biomass and even sometimes ad libitum (Corredor, 1978; McLarney, 1978; Popma, 1978; Philippart et al., 1979; Rifai, 1979 and 1980). But when mixed feeds (brewery waste, 99% and fish meal 1%) were used in semi-intensive cage culture of Tilapia, the feeding rate ranged from 15 to 30% of the biomass (Ibrahim et al., 1975).

Coche (1982) opined that food requirements per unit weight of fish decrease as the fish increase in size. In Ivory Coast, for example, it was shown that the daily feeding rate (DFR) had to be decreased from 60 to 4% of the fish biomass (B) after the fish had reached 40g average weight, to improve feeding efficiency (Coche, 1977). Melard and Philippart (1977) estimated the optimum DFR for O. niloticus in tanks and cages using a 46% protein commercial feed at 27 to 31°C. The DFR range from 30% reducing to 1.5% of the fish biomass for mean fish weight ranging from 0 to 300g. In the Philippines, Guerrero (1980) has also proposed a progressive reduction of DFR with increasing size for O. niloticus from 5% B (fish less than 50g) to 4% B (50 to 100g) and 3% B for larger fish.

2.4.7 Use of waste waters in aquaculture

The possibility of using waste water from sewage system for production of fish was outlined by Tapiador (1973) cited in Hjul (1974). Chan (1972) reported on the use of pollutants for aquaculture through the conditioning of wastes. Slack (1972) also gave a detailed report on sewage and aquaculture production. Pillay (1973) further drew attention to the use of domestic waste water as an ancient practice in fish culture and he mentioned the very high production obtained in sewage fish farming.

Huang (1968) cited in Hjul (1974) reported that from ponds in places where very high sewage water was abundantly available the production (of Tilapia) rate had been 6.5 to 7.8 metric tons per hectare per year. Sizes of the tilapia harvested ranged from 20 to 80g each. Fish weighing more than 40g were sold for direct consumption; fish less than 30g were sold to feed chickens, ducks and pigs. Tapiador (1973) reported on a commercial private fish farm utilising sewage water. The farm was producing 28.0 metric tons (Tilapia) per hectare per year in three ponds with a total surface area of 2.5 hectares. The fish stocking density was up to 70,000 fingerlings per hectare with a culture period of two to three months and crops a year. At harvest, the fish averaged 200g each. Hjul (1974) opined that fish raised in sewage water ponds could be marketed for human consumption, but in some areas or communities there would be aesthetic or other objections, including fears of contamination, especially if there was no proper treatment or control of the water.

Tapiador (1973) suggested that a 50-hectare sewage fish farm would be able to support a fishmeal plant turning out about 500 metric tons of fishmeal a year based on an average production rate of, say, 50 metric tons per hectare per year of the farm.

Tapiador (1973) therefore concluded that there is a good possibility for commercial fish meal production from aquaculture and, in particular from sewage fish farming. He, however, suggested that interested member countries of FAO or regional organisations should consider a pilot project in sewage fish farming.

2.4.8 Problems in cage fish culture

Beveridge (1987) opined that site selection and site evaluation are largely about choosing the right environment to farm the appropriate quantities of fish so as to minimize mortalities, maximise production and thus ensure that the venture be as profitable as possible. He further noted that unfortunately it is not often possible to choose the ideal site and neither is it also possible to foresee all the problems which might occur, or to examine all risks as thoroughy as one might like. Some of the problems associated with growing fish in particular climates or types of site are reviewed and where possible advice given to mitigate adverse effects. These problems are classified either as physical, biological, chemical or social.

2.4.8.1 Physical problems

(i) Currents

Recommended current conditions for cage fish farming are usually less than 50cm per second; much

greater than this, and there can be pronounced deformation of nets, excessive strain on conventional moorings and cage rafts/frameworks, and unacceptable losses of feed (Beveridge, 1987). According to Russian studies summarised by Privol'nev (1975), the flow rate inside cages should not exceed 20cm per second for trout, since above this rate energy expenditure on swimming increases markedly and growth and survival are adversely affected.

In Indonesia, traditional submerged carp cages used in running water are made from wood, which not only does not deform, but also greatly reduces current flow. The weight of the wooden cages is sufficient to keep them anchored on the bottom of rivers and canals, even during floods (Vaas and Sachlan,, 1957). Rigid mesh cages have also been used in fast flowing sites. In Bolivia, experimental cage culture of rainbow trout in the out flow of the River Hichukhota involved the use of 1 x 2 x 1m cages constructed from sections of 1cm plastic-coated wire mesh attached to a wooden frame (Beveridge, 1987). In Italy and Netherlands, where rafts of floating plastic-coated wire mesh rigid cages are used to culture trout and cyprinids in heated water power station discharges, systems of "Venetian blinds" have been installed upstream which can deflect some of the water past the cages during periods of high flow (Bronzi and Ghittino, 1981; Hogendoorn, 1984).

Metal mesh cages have also been used at marine sites in France and the Netherlands where currents are high (3 - 6 knots) (Boeuf and Harache, 1980; Anonymous, 1985).

(ii) Weather and climate

(a) Inclement weather conditions

Beveridge (1987) noted that certain areas suffer more violent storms than others by virtue of their geographical location or local topography. He further observed that the resulting wave action caused by heavy storms cannot only damage cage structures and moorings, but it can also injure fish through the pitching motion of nets, and can make routine jobs such as net changing and harvesting extremely hazardous.

Breakwaters are often used to reduce the effects of waves on coastal marine installations such as harbours and marinas, and a number have also been installed to protect coastal aquaculture projects in various parts of the world (Tazaki et al., 1975; FAO, 1977; Kogan and Romanycheva, 1979). Of the two basic types of breakwaters, the floating breakwaters have been suggested by a number of authors as being much more suited to the requirements of cage fish farming: they are relatively inexpensive to build, can be moored in deep or shallow water, do not interfere with currents and can easily be modified

as the farm expands or cages are moved (Tazaki et al., 1975; McGregor, 1978; Kato et al., 1979; Kerr et al., 1980).

Rigid copper alloy mesh cages are also reported to be extremely resilient to storm damage and several are currently in use at some of the more exposed North American locations (Woods Hole Engineering Associates, 1984).

(b) Light and weathering

Light is an important component in the fish's environment and it could have adverse effects on many of the materials used at the cage fish farm. Goldman and Horne (1983) observed that the light reaching the outer edge of the earth's atmosphere comes mainly from the sun, and has a broad and unequal spectral distribution. They further noted that as the light passes through the atmosphere, there is a selective scattering and absorption of wavelengths, particularly at either end of the spectrum, so that the light arriving at any particular point is greatly modified. Parrish et al. (1978) reported that the most damaging wavelengths in terms of the materials used in aquaculture and on fish and other living organisms are the lower (i.e. ultraviolet) end of the electromagnetic spectrum.

Both the cage frame work and any netting components which appear above the waterline - cover

(or top) nets, exposed portion of cage bags, etc - are prone to weathering, which is a term covering the combined effects of ultraviolet radiation (UVR), rain, wind, industrial smokes and microbial attack, although of these factors, UVR is reckoned to have the single greatest deleterious effect (Klust, 1982). Beveridge (1987) reported that the lifespan of most netting materials can be further extended by the addition of dyestuffs which absorb the light.

A number of studies have demonstrated that fish constrained in shallow aquaculture facilities such as cages or tanks without adequate cover can experience sunburn especially if the prevailing light levels are high (Hastein et al., 1980; Eiras, 1982; Bullock, 1982, 1984; Bullock and Coutts, 1985). It was therefore, concluded that some form of shade should be provided for caged fish whenever possible and this is particularly important where UVR levels are high, and where species known to be susceptible to sunburn are being grown. There is an approximate 4% increase in UVR levels for every 300m increase in elevation, and it is therefore not surprising that trout grown at high altitudes in a number of tropical countries, such as Mexico, Bolivia and Kenya, have been found suffering from UVR - induced damage (Bullock, 1984).

2.4.8.2 Biological problems

(1) Diseases

Representatives from more than 20 genera of bacteria have been isolated from fish, of which at least 15 species are recognised as actual or potential pathogens (Frerichs, 1984). Beveridge (1987) reported that wild fish often carry a wide range of parasites and other organisms which rarely prove fatal unless the fish are stressed by some other factors such as pollution, or the balance between host and pathogen is tipped in favour of the latter through the introduction of a novel host or strain of pathogen. He further noted that the establishment of a cage fish farm in a water body may disrupt existing parasite life cycles, by increasing the number of available hosts. Thus the risk of parasite transmission from wild to caged stocks can be very high. Farmed fish may frequently be stressed due to sub-optimal environmental conditions such as low oxygen, high temperature or light levels, or through handling or physical damage thus lowering resistance to disease (Wedemeyer, 1970; Snieszko, 1974; Shepherd, 1978). There is also some evidence that the risks of physical damage in cages is greater than in land-based systems. Nets treated with copper-based anti-foulants become hard and can abrade skin, particularly during storms or net-changing operations, possibly pre-disposing fish

to vibriosis (Needham, 1980), whilst in the USA, fin erosion in chinook salmon and steelhead rainbow trout have been attributed to cage conditions (Boydstun and Hopelain, 1977; Moring, 1982).

Even though disease prevention in fish is always preferable to cure, treatment of diseased stock may eventually have to be faced and Roberts and Shepherd (1986) recommended three basic methods:

- bath treatment, in which chemicals are added to the water.
- direct application of chemicals to the fish.
- administration of chemicals in the food.

Beveridge (1987) observed that even though these treatment methods could be easily administered in land-based fish culture systems, any chemical added to cages would soon be dispersed by currents and the swimming behaviour of the fish. However, treatment of caged fish is a long established practice in some parts of the world. In Kampuchea, for example, cow dung, mud and plant mixtures, tree back and salt are used to treat parasitic and fungal disease of caged gobies and catfish murrels, although the efficiency of these measures has not been properly evaluated (Pantulu, 1979).

(ii) Drifting objects

Floating and fixed mesh cages are particularly vulnerable to damage by drifting objects which can

tear holes in the netting, restrict water flow, even completely destroy cages (Anonymous, 1979). Jelly fish are common place in coastal waters during certain periods of the year, and great numbers can become entangled in cage nets causing net deformation and restricting water flow and so should be removed regularly. Jelly fish have also caused mass mortalities of caged fish in the Baltic (Koops, 1972).

A major problem faced by many caged fish farmers in inland tropical water bodies is drifting masses of floating plants, such as water hyacinth (Eichhornia crassipes) (Anonymous, 1979). In the Philippines cage fish farms, top nets are fitted to many of the cages so that during stormy periods, the whole cage may be submerged. An alternative solution to the drifting weeds is to build a deflective fence or barricade which can divert the weeds and keep the cage area clear (Guerrero, 1979).

(iii) Fouling

Fouling is a problem that occurs to a greater or lesser degree at all cage sites, irrespective of cage type. Beveridge (1987) reported that marine sites tend to be worse than freshwater in this respect, particularly if the environment is warm and organically rich, and if the prevailing currents, which greatly influence settlement, are low. He further emphasized that the degree of fouling is also dependent upon

the material used, mesh size, whether the mesh is knotted or knotless and is, to some extent, influenced by the species being cultured. Biofouling is not a major problem in the culture of herbivores, such as some of the tilapias (Pantastico and Baldia, 1981). In Japan, yellowtail cages have been found to accumulate fewer fouling organisms than those holding blue fin tuna or red seabream due to the action of the fish which continually brush past the netting (Kuwa, 1984). Studies of the rates of fouling of net cages and the organisms involved have been detailed for many different parts of the world (Milne, 1970; Moring and Moring 1975; Cheah and Chua, 1979; Wee, 1979; Kuwa, 1983, 1984; Santhanam et al., 1984).

Fouling has been observed to reduce the actual mesh size, thereby cutting down on the flow of water through the cage and increasing drag (Milne, 1970; Inoue, 1972; Wee, 1979; Kuwa, 1983, 1984; Santhanam et al., 1984). The increases in the weight of fouling recorded by Milne (1970) not only affect routine handling, but also floatation. Milne (1976), and Hugenin and Ansuini (1978), have stated that a number of net failures, due largely to fouling, have occurred at several large commercial marine cage fish farms.

Beveridge (1987) recommended a number of options to solve or mitigate the fouling problem if it is severe:

(a) adjustment of the cage fish farm management procedures

(b) use of chemical or biological agents

(c) option for a fouling-resistant or rotating design.

The first option involves the routine business of net changing and clearing that most farms practise on a regular basis. If fouling is severe, then the farmer can simply choose to carry out this procedure more frequently.

An alternative option is to use chemical antifouling agents. According to Lovegrove (1979) most antifouling agents contain a biocide which slowly leaches so that the surface is permanently surrounded by a thin layer of toxic material which prevents the susceptible juvenile planktonic stages of fouling organisms from gaining a foothold.

Beveridge (1987) reported, that antifouled nets provide a measure of protection for many months, although the degree of protection declines rapidly after six months or so and that in temperate regions, nets have to be treated each year. He noted that the cost of treatment will add approximately 20 - 25% on the cost of a knotless nylon cage net. Good et al. (1979) and Waldock and Thain (1983) observed that the copper and organotin compounds used as antifoulants are toxic to shellfish, although the latter appear to be worse. Tin-containing antifouling paints used to protect cages have also been implicated in deformities of yellowtail in Japan (Anonymous, 1982).

Considering the biological antifouling option, it was observed that the organisms which foul net cages may augment the diets of cultured herbivores or detrivores, they are only occasionally ingested by carnivorous species such as the salmonids and play a negligible role in their diet (Moring and Moring, 1975). However, in several countries herbivores have been stocked alongside commercially more important species in attempts to reduce biofouling (Beveridge, 1987). In Palau, Hasse (1974) successfully used siganids (S. canaliculatus and S. lineatus) at densities of approximately 2 fish per m^3 to reduce fouling in cages holding strings of oysters (Ostrea nomades), whilst Chua and Teng (197 and Aquacop (1975) have found siganids effective in curtailing fouling in cages of grouper and carangids. In Japan, the striped and spotted knifejaws, Oplegnathus spp., have been used in cage mariculture (Kuwa, 1983, 1984), and low densities (1 fish per $5m^3$) of rohu (Labeo rohita) have proved effective in maintaining the cleanliness of carp cages in Nepal (Sharma, 1979). Marine prawns have also been used in salmon cages, and mullets with pompano and other species (Swingle, 1971; Tatum, 1974; Aquacop, 1975; Rensel and Prentice, 1979). However, it was reported that there would be problems: signanids have been found to damage cage netting as a result of grazing (Ben Yami, 1974), and

Knifejaws have been observed attacking the tails and fins of sick yellowtail (Kuwa, 1984).

In respect of option for a rotating design, a number of rigid cages have also been designed using more fouling-resistant materials such as galvanised steel, PVC coated wire and copper or copper-nickel compounds (Milne, 1970; Swingle, 1971; Powell, 1976; Ansuini and Hugenin, 1978; Ojeda and Strawn, 1980 ; Hugenin et al., 1981; Kuwa, 1983, 1984).

(iv) Predators

In a survey carried out by Mills (1979) in Scotland, it was observed that nearly 90% of fish farms (including cage fish farms) were visited at some time or other by piscivorous birds. The range of predators reported from cage fish farms is enormous, and includes fish, lizards, squid, sea snakes, turtles, birds and mammals (Table 2.5). Beveridge (1987) reported that most predators, particularly birds and mammals, exhibit diurnal patterns of activity, preferring to attack their caged prey at dawn and dusk when staff (of the cage farms) are usually absent from the farm. He further noted that clear, calm nights, too, are often used by predators. It was observed that predators are also sometimes inadvertently introduced when the cages are initially stocked or when nets are changed (Reksalegora, 1979).

Table 2.5 Predators at cage fish farms

Country	Cultured Species	Predator	Comments	References
USA (Washington)	Salmon	Spiny dogfish (Squalus acanthias)	Particular problems with larger mesh sizes.	Mahnken (1975); Lindbergh (1979)
USA (Maine)	Trout	Mink, Otters	Used vinyl-coated metal mesh cages to deal with problem	Anon. (1981)
Canada (New Brunswick)	Salmon	Gulls (L. argentatus and L. marinus), Great blue herons (A. herodias), cormorants (P. auritus)	Large number of unrecorded losses attributed to birds	Henderson (1980)
UK (Scotland)	Salmon and Trout	Seals, Otters, Cormorants mergansers, guillemots, gannet, goosander, herring and black gull	List compiled from 38 farms, both marine and freshwater	Mills (1979)
UK (England)	Trout	Gulls, grebes, cormorants	Damage to nets by diving birds	Anon. (1978)

Table 2.5 (contd.)

Country	Cultured Species	Predator	Comments	References
Norway	Salmon	Herons, gulls, cormorants, seals	More than 50% losses at some farms attributed to predators, recommend anti-predator nets	Moller (1979)
Israel	Sparus sp.	Moray eels, squid	Lots of small fish also found in cages	Pitt et al. (1977)
Malaysia	Marble goby	Snakeheads, water snakes	Damage to nets and mortalities in freshwaters	Jee (1978)
Malaysia	Grouper sp	Otter (L. sumatrana), gulls, puffer fish (Sphaeroides sp)	Nets damaged by puffer fish. Dogs used to scare otters. Stout PE anti-predator nets introduced	Chua and Teng (1980)

PE = Polyethylene

Jee (1980) reported that predatory fish can also on occasion damage nets. Chua and Teng (1980) noted that puffer fish (Sphaeroides sp) damaged the net bags of grouper resulting in 20% loss of stock. Ranson and Beveridge (1983) have suggested that diving birds, such as cormorants rarely manage to extract fish from a cage, although they can certainly wound many. During a survey of a freshwater rainbow trout cage farm in Scotland, it was estimated that up to 6% of all caged fish showed signs of wounding by birds, at certain times of the year (Ranson and Beveridge, 1983). Diving birds have also been implicated for damage to nets (Ranson and Beveridge, 1983).

Beveridge (1987) noted that attraction of birds and mammals to a cage farm can affect disease risks, since many animals play major roles in the life cycles of commercially important diseases. Roberts and Sommerville (1982) observed that the predatory heron is an important intermediate host in the life cycle of the cestode Diphyllobothrium sp., a parasite which is prevalent at a number of UK cage trout farms, whilst otters (Lutra sp.) are known to act as final hosts for the digenean Haplorchis, a common parasite of tilapias. Ranson and Beveridge (1983) speculated that the extent of scale loss and wounding on many of the fish attacked by birds if not sufficient to kill them directly, have provided a site for invasion by fungi or bacteria.

Needham (1980) has also suggested that even unsuccessful attacks on caged Atlantic salmon can stress their immune system thus increasing susceptibility to disease.

Farmers, however, have deviced measures to counter the menace of predators on cage fish farms. Beveridge (1987) reported that the use of top nets to deter gulls and herons, and antipredator nets to foil under water attacks is common. Other measures commonly employed against predators include the use of dogs in tropical countries to deter otters and rats (IDRC/SEAFDEC, 1979). A number of deterrents, such as scarecrows, flashing lights and devices which emit loud noises or distress calls are marketed to try and frighten off birds and even seals, but to date these methods have had limited success, as most predatory species soon habituate to them (Meyer 1980 ; Martin, 1982; Salmon and Conte, 1982). Live traps are sometimes employed against mink while shooting is also resorted to by a number of farmers. Ranson (1982) noted that shooting often does not work. He observed that there are numerous accounts of how shooting cormorants makes no difference to the numbers feeding at a farm, since the visiting birds usually come from several different colonies. Hugenin et al. (1981) reported that rigid mesh cages (unlike flexible mesh cages much reviewed above) are, of course, much superior in terms of resistance to damage and infiltration by predators,

providing that they are fitted with adequate protection above the waterline.

(v) Wastes

Results from a number of studies have demonstrated that the quantity of material sedimenting under fish cages at intensively managed farms is usually at least an order of magnitude higher than that recorded at control sites or in undisturbed water bodies (Kadowaki et al., 1978, 1980; Enell and Lof, 1983; Collins, 1983; Mericas and Phillips, 1985; Phillips et al., 1985). Increases in bacterial numbers and macroinvertebrates have been observed at a number of intensively farmed freshwater sites (Eley et al., 1972; Kilambi et al., 1978; Korzeniewski and Korzeniewska, 1982; Tsutsumi and Kikuch, 1983). Enell (1982) and Enell and Lof (1983), in studies of laboratory - incubated cores, found that the rate of oxygen uptake was more than twice as high in cage sediments than those taken from a control site. Evidence for anoxic conditions in sediments under fish cages has been reported in a number of studies (Arizono and Suizu, 1977; Breaten et al., 1983; Nishimura, 1983; Stewart, 1984). Kafuku and Ikenoue (1983) opined that another theory which remains untested is that there may be a build-up of facultative disease organisms in the sediments under cages, and that disease outbreaks at long-established farms may be more common.

Braten et al. (1983) suggested that the following are taken as signs of a growing problem:

(a) periodic smell of sulphur and methane, especially during summer and autumn

(b) the appearance of gas bubbles at water surface,

(c) the rapid build-up of anoxic (black) sediments under cages, with pockets of trapped gas (This may necessitate periodical examination of the muds under the cages by divers).

(d) extensive gill damage (Gills may appear pale, sometimes with dark patches; filaments are swollen, fused, or badly damaged).

If the accumulation of wastes under cages is perceived as being a major threat to fish production, Beveridge (1987) recommended that the wastes must either be removed from the vicinity of the caged fish, or the farm relocated at a new site. Scavenging red (Chrysophrys major) and black (Mylio macrocephalus) sea breams have been stocked inside grouper cages in Hong Kong in an effort to reduce waste feed output (Tseng, 1983).

Sudden algal bloom in high eutrophic lake has been associated with mass fish kill, an example is the mass fish kill after the algal bloom in Laguna Lake in July, 1975 (Anonymous, 1979).

2.4.8.3 Chemical problems

(1) Acidified waterbodies

Beveridge (1987) reported that the pH of a water body is determined by the interaction of the rate of deposition of acids from the atmosphere and rate of neutralisation in the catchment area. Acid deposition, principally in the form of rain or snow, is a natural phenomenon, the pH of pure water in equilibrium with atmospheric CO_2 being 5.6 (Overrein et al., 1981). Catchments which are composed of hard, slow-weathering rocks such as granite, gneiss or quartz sandstone are poor at neutralising acid precipitation and also give receiving waters their characteristic low ionic and high humic acid content (Beveridge, 1987).

If acidification is taking place, Beveridge (1987) suggested two methods of combating this problem:

(a) control of the acidification process by chemical dosing and

(b) change to a more acid-tolerant species.

Baker (1984) observed that over the past 50 years or so a wide range of neutralising substances has been used, including limestone ($CaCO_3$), lime (CaO and $Ca(OH)_2$), soda ash ($Na_2 CO_3$) olivine [$(MgFe)_2 Si O_4$], fly ash and industrial slag, and sodium hydroxide (NaOH). He opined that, as far as the fish farmer is concerned, limestone is probably the best: it is

safest, cheapest and overall the most effective on a wide range of lake types. A number of different application methods have been tried, although from the cage fish farmer's point of view, Beveridge (1987) noted that direct dosing of the lake as opposed to the inflows or the watershed is likely to be most cost effective. Finely crushed limestone can be added to the lake as a slurry, spread with the aid of a device as described by White et al. (1984). An alternative method is to spread crushed limestone (0.25 - 0.75mm diameter) into shallow areas where wave action and currents help keep it 'activated' (Hasselrot and Hultberg, 1984; Krester and Colquhoun, 1984). In Scandinavia and North America, the dose rates of between 10 and 30g per m^3 lake water are used, the exact amount depending upon the severity of the problem, lake retention time, lake type and method used (Hasselrot and Hultberg, 1984; Krester and Colquhoun, 1984; Rosseland and Skogheim, 1984; White et al., 1984). Lakes with slow flushing rates unlike those with fast flushing rates (< $1y^{-1}$), have maintained good pH values for 5 years or more following a single dose with crushed limestone (Hasselrot and Hultberg, 1984; White et al., 1984).

(ii) Oxygen

Beveridge (1987) reported that the dissolved oxygen (DO) regime in a fish cage is a balance between input and output. As oxygen input by diffusion across

the air/water interface is negligible - Kils (1979) estimated that it provided somewhere in the region of 0.5% of the oxygen respired by caged fish - tbe major source of DO is water flowing through the cage as a result of external currents and the movements of the caged fish. Beveridge (1987) noted that at most sites the DO content of the surface waters approximates saturation levels and as long as the cages are maintained relatively free from fouling there should be few problems. Beveridge (1987) further explained that DO levels can fall far below saturation in natural water bodies under the following circumstances:

(a) where the phytoplankton community is large (i.e. under bloom conditions), night-time respiration can cause a marked decline in DO reaching a minimum around dawn.

(b) at the end of a phytoplankton bloom, bacterial decomposition of the algae can lead to anoxia.

(c) upwelling of anoxic water from the hypolimnion to the surface can occur at certain sites given the right combination of environmental and climatic conditions.

He recommended that in many instances these problems can be avoided during the site appraisal stage by rejecting eutrophic or strongly stratified water

bodies. Nevertheless this is not always possible or even desirable (e.g. extensive fish farms are best sited in eutrophic water bodies) and problems have been reported at both marine and freshwater sites in temperate and tropical environments (Inoue, 1972; Koops,, 1972; Grave, 1975; Barica, 1976; Kils, 1979; Landless,1985).

Beveridge (1987) observed that there has been little study of aeration in cages and thus it is difficult to assess which aeration (airstones/ venturis/air-lift pumps/submerged pumps) are best, or even how effective aeration in cages is. A number of examples are cited by Landless (1985) in which air-lift devices have proved effective in maintaining good DO levels at cage farms subject to blooms. However, according to Kils (1979) submerged airstones can actually make oxygen conditions worse by creating a rising stream of oxygenated air which rapidly flows across the surface and out of the cage, the displacement of cage water resulting in an upwelling of deoxygenated hypolimnetic water which, if the cages are located near the lake or sea bottom, could also carry in cage wastes.

2.4.8.4 Social Problems

(i) Poaching and Vandalism

In general, cages are more vulnerable to poaching and vandalism than any other type of aquaculture

venture (Anonymous, 1979). Beveridge (1987) observed that farms sited some distance from shore-based offices and staff accommodation can easily be visited by poachers/vandals without observation, particularly at night. Anonymous (1979) noted that fish may be simply and quickly removed from cages by hand net, whilst vandals can cause huge financial loss considering the damage and loss of valuable stock in minutes using nothing more sophisticated than a sharp knife. In many parts of Asia, guard houses are built on the cage rafts and night watchmen with dogs employed to guard stock (IDRC/SEAFDEC, 1979; Tseng, 1983). Beveridge (1987) reported that in the UK one large cage fish farm has moored an old fishing boat which serves as accommodation for staff on night duty, alongside the farm. He stressed that certain types of cage are less vulnerable than others: rigid mesh cages cannot be vandalised so readily, and it is also more difficult to remove fish without the appropriate equipment. Anonymous (1984) gave details about a number of devices under trial to help protect cages, including a high pressure cable system, first developed for safety applications in the mining industry, which is laid along cage walkways and can be laced through the netting. When twisted, compressed or stretched, it can activate a range of alarm systems, including a klaxon, warning lights, radio paging device and camera. Beveridge (1987) reported that radar has also been

successfully employed at a number of larger salmon farms in the UK and will warn on anyone entering the site. He also mentioned that lockable lids are also incorporated into some smaller cage designs. Beveridge (1984) opined that sometimes, socio-economic problems lie at the root of the problem (poaching and vandalism). In some parts of the world, the penalties for poaching, have been increased. In Alabama, USA, for example, a bill was introduced in the early 1980s to stiffen penalties (jail term and or fines) for anyone convicted of catfish rustling (Beveridge, 1987).

However, Anonymous (1979) reported that maintenance of good relations with the people in the area (where the cage fish farm is located) is the most effective way of preventing poaching and vandalism.

2.5 Profitability of cage fish culture

Profitability in cage fish culture depends on various factors like locality, fish species, growth rate, costs of materials and labour, access to market and level of management (Fujiya, 1979; Galapitage, 1982; Mane, 1981; de la Cruz, 1982 and Guerrero, 1982). They concluded that there are no generalizations concerning profitability in this system of culture.

de la Cruz (1982) comparing the yield from fish cage/pen system with that from pond culture system (in the Philippines) concluded that the yield from the former is 3.5 to 4.3 times more than the production

in the latter. He emphasized that based on the profitability of cage culture system and with the view of providing an alternative culture system under a bank-financed project, an FAO team recommended cage culture of Tilapia nilotica to be operated by a number of families sub-borrowers. The estimated income per cage (size 10m x 30m x 3m) suggests that a family just needs to operate four cages to exceed the combined estimated income from a 2.5ha fish pen and 2 cages owned by two families; and eight cages instead of 10-ha fish pen and fish cages with multiple ownership (de la Cruz, 1982).

Another example of profitability of cage culture system is the yellow tail culture in floating cages in Japan. Fujiya (1979) reported that the average production of family size yellowtail farmer is 10 - 30 metric tons annually. This production from yellowtail farming, he concluded, assured the farmer of a middle class income in Japan.

In Thailand, it has been shown that the average income of fish farmer is about six times more than that of an agriculture farmer and substantially higher than that of a coastal small-scale fisherman (FAO, 1975). In Hungary, it has been reported that fish production costs are 49, 30 and 2% less than beef, poultry and pork respectively; while, in India the profits obtained in fish culture per weight of produce can be 3 - 4 times

higher than that of wheat, rice and millet (Pillay, 1977). Farming of the channel catfish (Ictalurus punctatus) in the United States of America showed that intensive culture in floating net-cages and fence enclosures yield highest rate of returns on investment of 121 - 160% compared to pond and raceway culture (22 - 55%) (Shang, 1976). In Scotland, several companies produce in excess of 1,000 metric tons of Atlantic salmon in cages although not all are produced at the same site and have an annual turnover of close to £4 million (Beveridge, 1987).

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Description of Lake Kainji area

The five experimental sites where the studies were carried out are located around Lake Kainji basin (Figure 3.1). The lake covers an area of 1270 km², it is 139 km long and 24 km at its widest point. It is situated between longitudes 4°22' and 4°45' east and latitudes 9°50' and 10°55' north in the north-western part of Nigeria at kilometre 1008 to 1144 of the 5872 km along River Niger. Kainji Lake basin lies on the border of the sub-Sudan and Northern Guinea Savanna (Clayton, 1957; Keay, 1959). The climate in the area is governed by two main winds: the Southwest wind from the Atlantic Ocean and the Northeast wind from the Sahara. The area experiences two distinct seasons: the wet season (April - October) and the dry season (November - March). At Kainji Dam site, the mean daily temperature range from 19.2°C to 37.5°C. The annual total rainfall is 1181.16mm, while the relative humidity range from 19.5% to 75.1%. Northerly winds dominate in the dry season while southernly winds predominate in the wet season (Table 3.1). Lake Kainji (within which three of the experimental sites

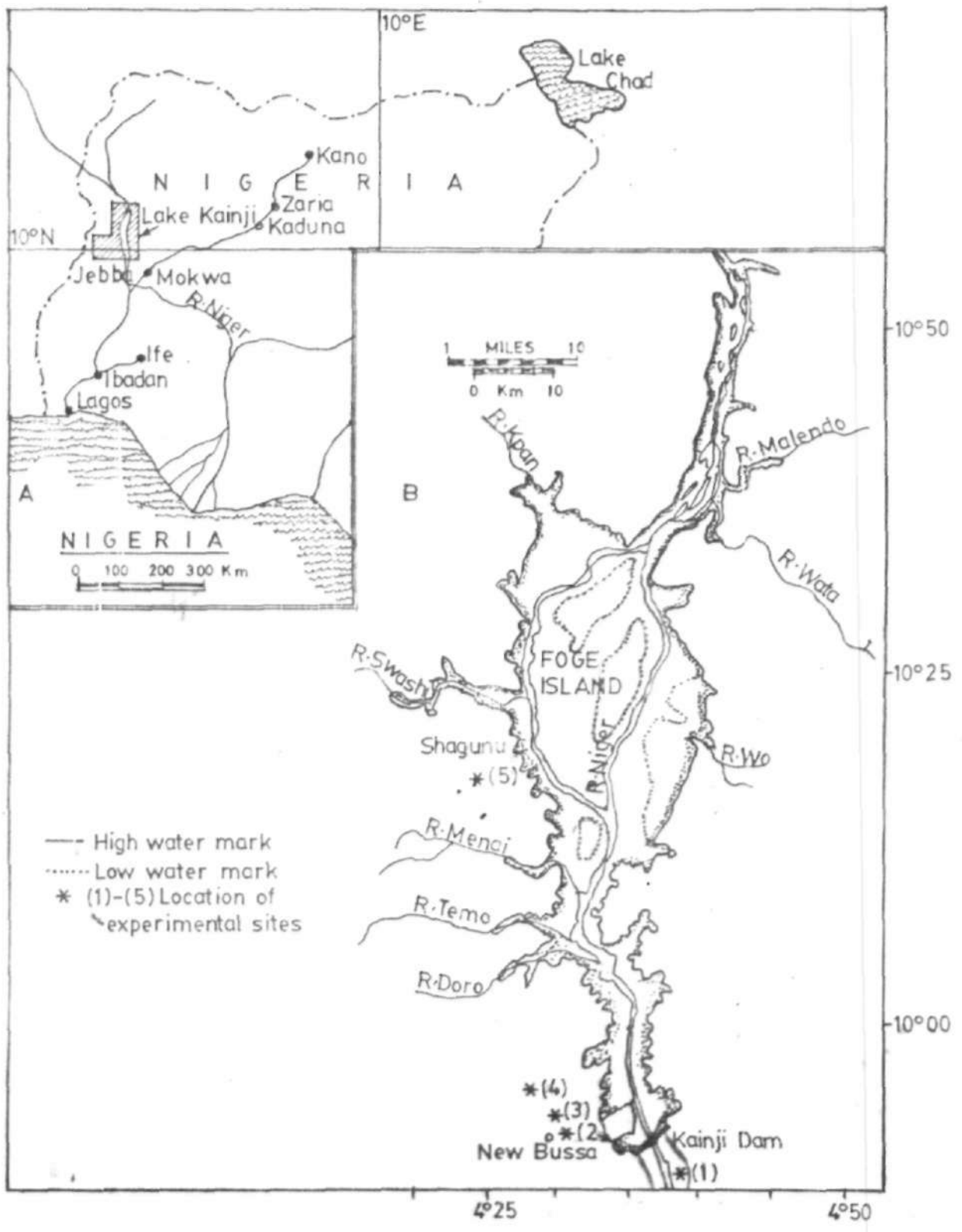


Fig. 3.1 A. Nigeria showing location of Lake Kainji.
B. Lake Kainji

(1) Intermediate Basin (2) Dogongari Bay
(3) Kigera III Reservoir (4) NEPA Sewage Pond (5) Shagunu Bay

Table 3.1 Some Meteorological Data obtained at Kainji Dam Site in 1990

Month	Mean Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	Wind Direction
	Max.	Min.			
January	33.6	19.5	NIL	29.0	Northerly
February	35.1	22.0	NIL	28.9	Northerly
March	37.4	22.8	NIL	19.5	Northerly
April	37.5	26.6	35.83	47.8	Southerly
May	32.8	24.3	166.50	66.0	Southerly
June	32.6	24.4	172.18	68.5	Southerly
July	30.1	22.9	327.10	75.1	Southerly
August	30.5	22.8	212.42	73.2	Southerly
September	31.2	22.2	197.02	70.6	Southerly
October	32.7	22.3	70.11	67.5	Southerly
November	35.8	19.9	NIL	51.6	Southerly
December	35.4	19.2	NIL	44.8	Northerly

Source: NEPA Hydrology Department, Kainji.

were situated) is the largest man-made lake (built for generation of electricity) in Nigeria. There are two distinct periods of floods in the Lake Kainji area. The major one called the "White Flood" comes from areas stretching from Niamey downstream and represents the run-off from local rains (including those of Nigeria) which carry large quantities of colloidal clay, mainly kaolinitic in origin (Nedeco and Balfour Beatty, 1961). The second flood called the "Black Flood" carries less silt and comes from the headwaters of the river (Niger) and takes about five to six months before reaching Kainji in November.

The physical, chemical and biological characteristics of the lake have been reported by several workers (El-Zarka, 1971, 1973; Henderson, 1973; Imevbore and Adegoke, 1975; Adeniyi, 1978). There are frequent occurrences of algal blooms in the lake especially during the month of October (Adeniji, 1973).

3.2 Description of the experimental sites

Five experimental sites around Lake Kainji and New Bussa were used for the studies.

3.2.1 The Intermediate basin

Figure 3.2 shows the Kainji Dam with its navigation locks which comprise of upper lock and

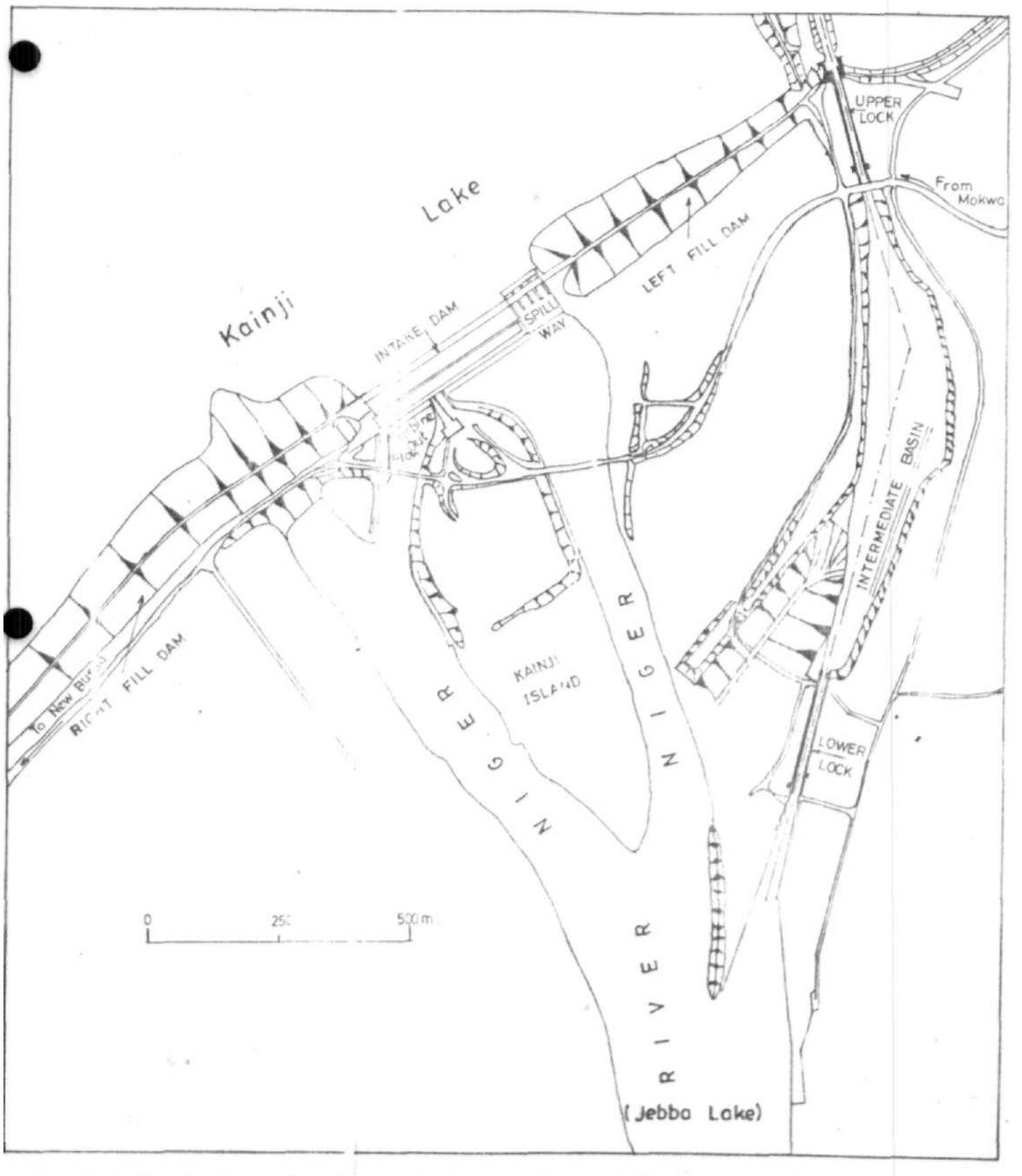


Fig. 3·2 Kainji Dam showing navigation locks and the Intermediate Basin.

lower lock. This lock system can be operated to allow big boats (vessels) to move from the lake to the river below the dam or vice versa. The Intermediate Basin which is about 1.5 ha in surface area is located between the upper and lower navigation locks. The bottom of the basin is muddy.

3.2.2 The Dogongari Bay

The Bay is located on the west of Lake Kainji close to the Niger River Basin Development Authority farm land, New Bussa (Figure 3.1). The maximum surface area of the Bay at the highest water level is more than 50 hectares but about 30 hectares at the lowest water level. The average draw down in the Bay is about 50%. The deepest water level at the site was 9m, the minimum was 3m and the average was 5.5m. The minimum water level at the site is usually recorded between June and July. The Bay is affected by the two major floods (Black flood and White flood) in the lake.

3.2.3 Kigera III Reservoir

This is a drinking water reservoir located within the National Institute for Freshwater Fisheries Research (NIFFR) Housing Estate at New Bussa. It was constructed in 1980 by damming

a seasonal stream. The reservoir is about 0.4 ha in surface area and 2m average depth at maximum water level. Water replenishment into the reservoir during the dry season was done by pumping water from Lake Kainji. Apart from wild fish species especially Barbus sp that exist naturally in the reservoir, some fish species like Tilapia, Clarias sp and Heterotis niloticus were stocked into the reservoir for small reservoir fisheries management studies (Ita et al., 1984).

3.2.4 NEPA sewage pond

This 0.4 ha surface area (about 1.5m average depth) site is located behind the Niger State Ministry of Agriculture and Natural Resources office at New Bussa. The sewage pond was designed by Balfour Beatty and constructed around 1972 by Impregillo (a construction firm that built the National Electric Power Authority (NEPA) Kainji Dam). The sewage pond receives waste waters from the New Bussa resettlement quarters and the NEPA residential quarters with a population of about 3,000 people. The bottom of the pond is muddy while its inner slope is concreted to fortify the dikes. It has an inlet pipe (30cm in diameter) which brings the residential waste waters into the pond (Plate I) and a 23cm outlet pipe (at another end of the pond) for spilling excess water



Plate I Sewage pond showing inlet pipe (IP) and some modules of floating cages (MC).

especially during the rainy season. During the experimental period, the pond water surface was occasionally covered by duckweeds, Lemna sp. This sewage pond had earlier been directly stocked with fingerlings of Cyprinus carpio and Sarotherodon galilaeus in an experiment to study the growth and survival of the two fish species in the waste water (Okoye et al., 1986).

3.2.5 Shagunu Bay

This site is northerly about 62 km from the Kainji Dam and at the western side of the middle basin of Lake Kainji (Figure 3.1). This portion of the lake is about 50 ha in surface area at the maximum water level. The bay contains many submerged tree stumps. The water depth at the culture site ranged between 3.0m to 10.5m (mean 5.5m). The bottom of the bay varies from mud, gravels to rock in some areas. Mean water transparency was 0.3m between August and November; 0.4m between November and February and 1.3m at other months (i.e. March to July).

3.3 Layout, design and construction of the culture system

3.3.1 Floating raft layout, design and construction

The basic components of the floating raft are:

(i) The framework or raft to which the net cages (or hapas) are attached.

(ii) The floats which keep the raft bouyant with all its attachments.

(iii) The anchor line at the lower end of which is the anchor or mooring device.

3.3.1.1 Raft layout/design

Seven raft layout/designs were used for the various experiments conducted during the course of this study:

(i) 9m x 6m (L x B) with six, 3m x 3m apartments

(ii) 9m x 9m with nine, 3m x 3m apartments

(iii) 9m x 9m with sixteen, 2.25m x 2.25m apartments

(iv) 7m x 7m with four, 3.5m x 3.5m apartments

(v) 6m x 6m with sixteen, 1.5m x 1.5m apartments

(vi) 6m x 6m with four, 3m x 3m apartments

(vii) 5m x 5m with sixteen, 1.25m x 1.25m apartments

(where L = length, B = breadth)

3.3.1.2 Raft construction/launching

The following materials were used in raft construction: bamboo poles (especially mature Bambusa vulgaris Schrad-ex-Wendel), 6 inches nails, kuralon No. 15 rope.

Procedure

(i) The bamboo poles were trimmed (at the thinner upper ends) into the required lengths

(9m, 7m, 6m, or 5m) depending on the dimension of the raft. For example, in constructing a 6m x 6m (L x B) with 16, 1.5m x 1.5m apartments raft, 26 bamboo poles were trimmed with the carpenter's saw to about 6m length each.

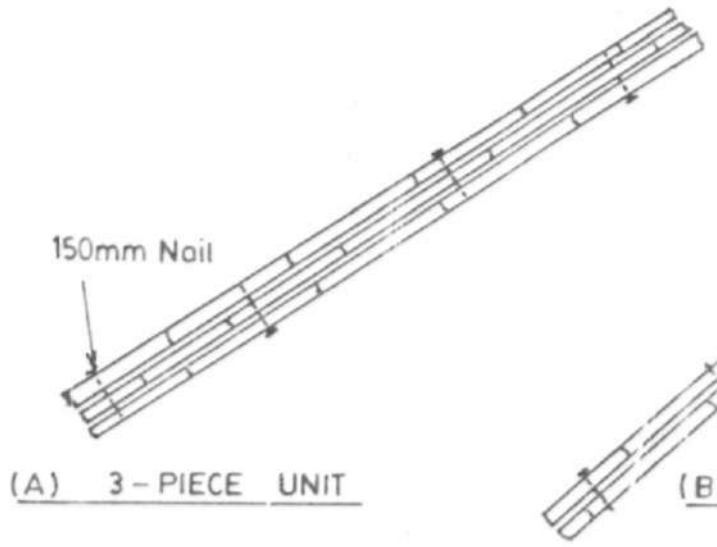
(ii) Three of these trimmed bamboo poles (now referred to as a 3-piece unit) were nailed together at close intervals using 6 inches nails (Figure 3.3A). Six of these 3-piece units were made and kept aside.

(iii) So also the remaining eight trimmed bamboo poles were nailed together in twos to produce four, 2-piece units (Figure 3.3B).

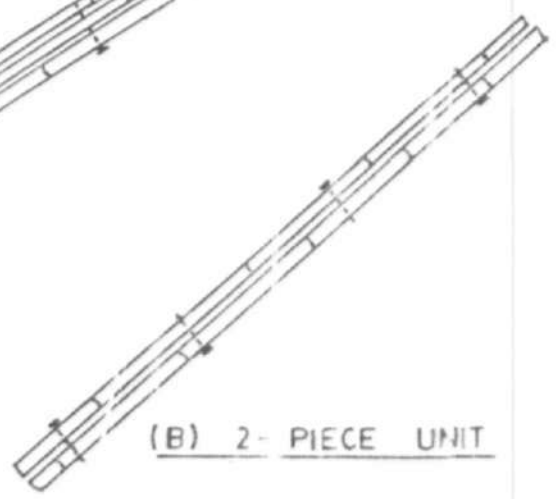
(iv) Four of the 3-piece unit were laid-out to form a square (about 6m x 6m) such that two 3-piece units were laid parallel underneath another parallel set of two 3-piece units (Figure 3.3.C) and nailed together at the four intersection with 6 inches nails.

(v) One, 3-piece unit was then placed equidistant in between the upper parallel set of two, 3-piece units and nailed at the two intersections (Figure 3.3.D) (Plate II).

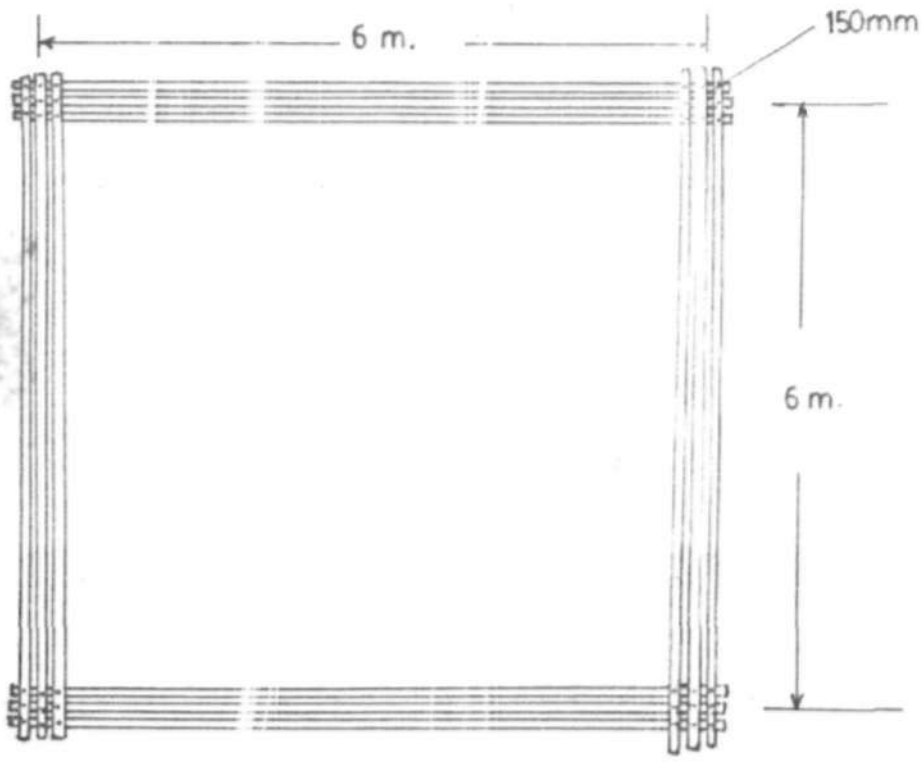
(vi) Another one, 3-piece unit was again further laid to divide the raft into four, 3m x 3m apartments and nailed at three intersections (Figure 3.3.E).



(A) 3 – PIECE UNIT



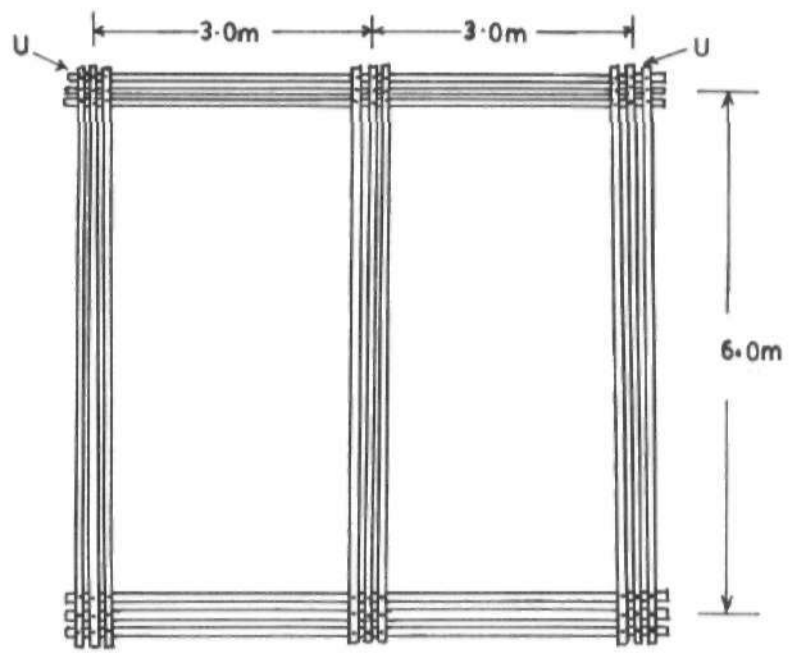
(B) 2 - PIECE UNIT



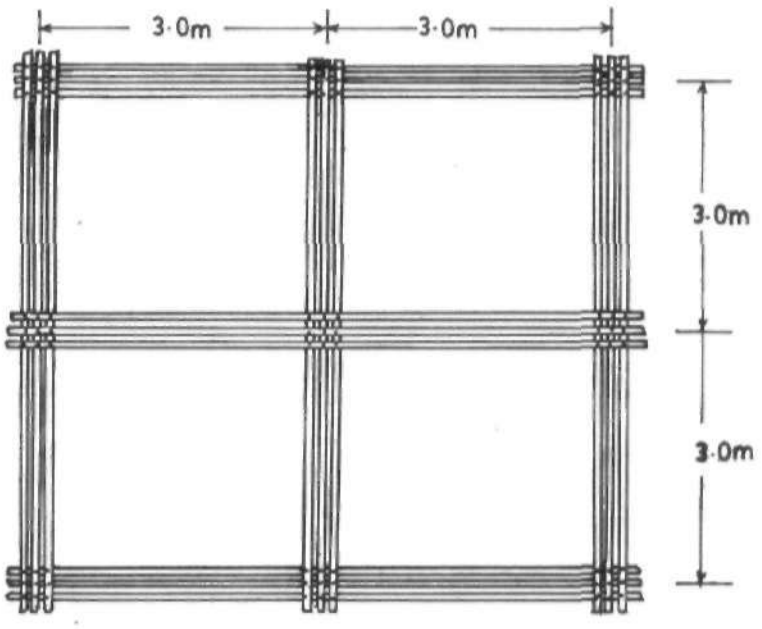
(C) FOUR OF THE 3-PIECE UNITS LAID OUT (6m x 6m)
AND NAILED TOGETHER AT THE FOUR INTERSECTIONS

Fig. 3·3 Stages of Raft Construction

Fig. 3·3 cont'd



(D.) ONE, 3-PIECE UNIT PLACED EQUIDISTANT BETWEEN THE UPPER PARALLEL SET OF TWO, 3-PIECE UNITS (U) AND NAILED DOWN



(E.) ANOTHER ONE, 3-PIECE UNIT, FURTHER LAID AND NAILED, DIVIDING THE RAFT INTO FOUR APARTMENTS.

N. B. THIS RAFT IS IDEAL FOR THE COMMERCIAL GROW-OUT.



Plate II Bamboo raft under construction.

(vii) To finally obtain a sixteen, 1.5m x 1.5m apartments, four, 2-piece units were juxtaposed between the 3-piece units such that each of the sixteen apartments was uniform in size (about 1.5m x 1.5m) and then nailed at all the 16 intersections (Fig. 3.3F).

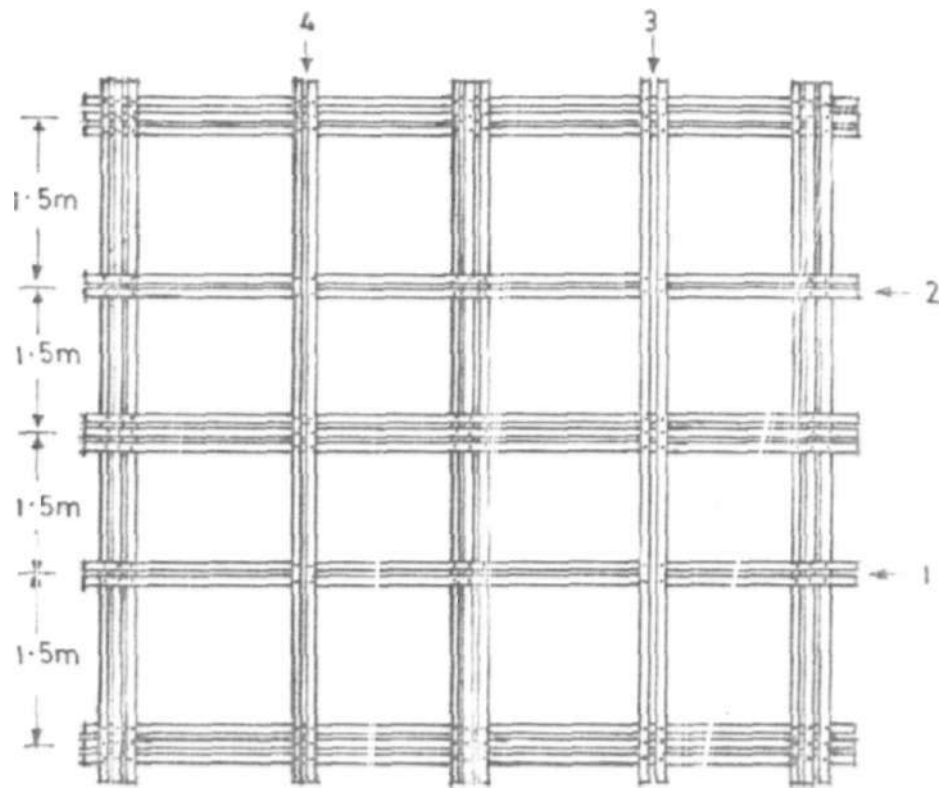
(viii) The four main peripheral intersections were then tied together with kuralon No. 15 ropes to strengthen the raft.

(ix) In order to increase the life span of the raft, either four 200-litre empty but coated metal drums or nine 100-litre plastic kegs were fastened to the bamboo raft using 6mm diameter iron rods (Figure 3.4).

(x) The complete raft with floats was then carried by hand by about eight adults and launched on the surface of the water body and paddled like a boat or towed away with a motorized boat to the site for the cage culture (Plate III).

(xi) After paddling or towing the raft to the desired site on the water body, an anchor rope (polypropylene 10mm diameter) with about 30-kg concrete block was used to anchor the raft at each of its four main corners. The length of each anchor rope was thrice the depth of the water at the site in order to allow for sag and also

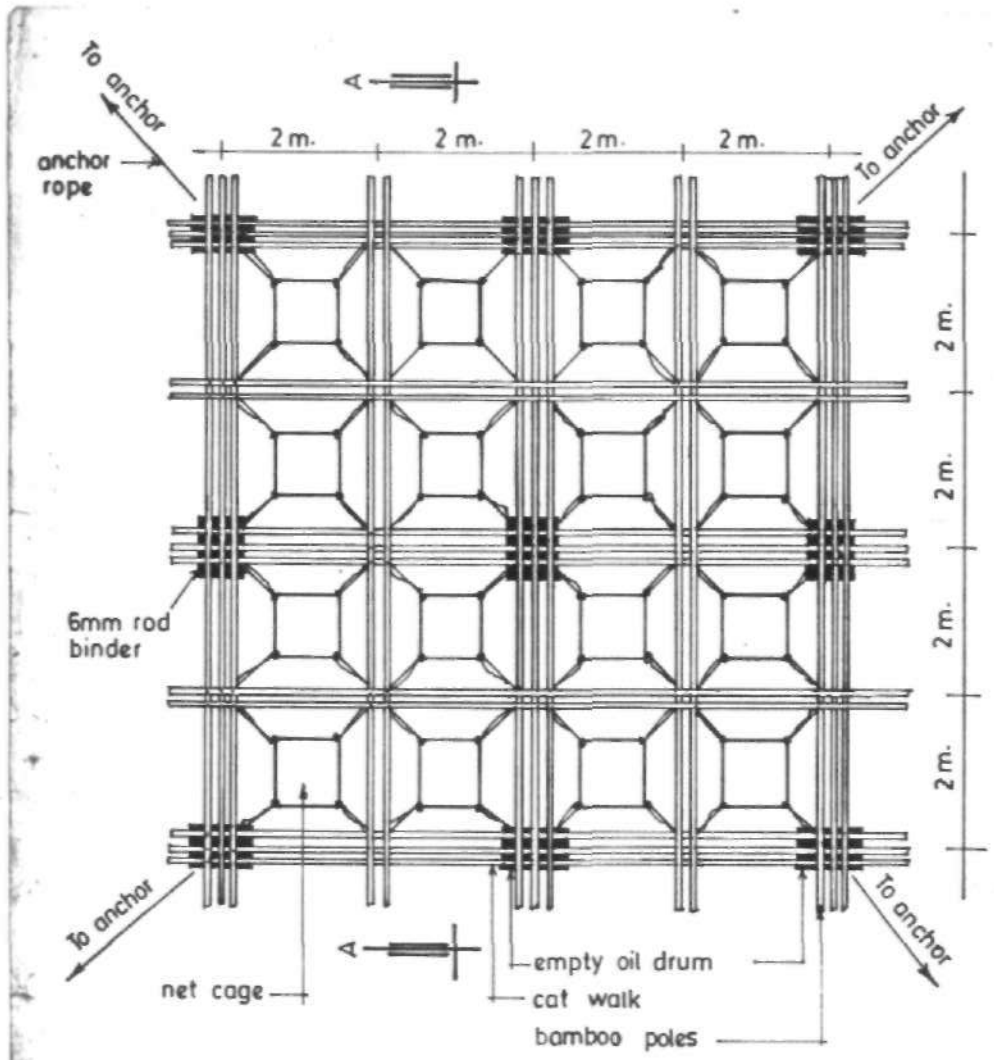
Fig. 3 3 cont'd



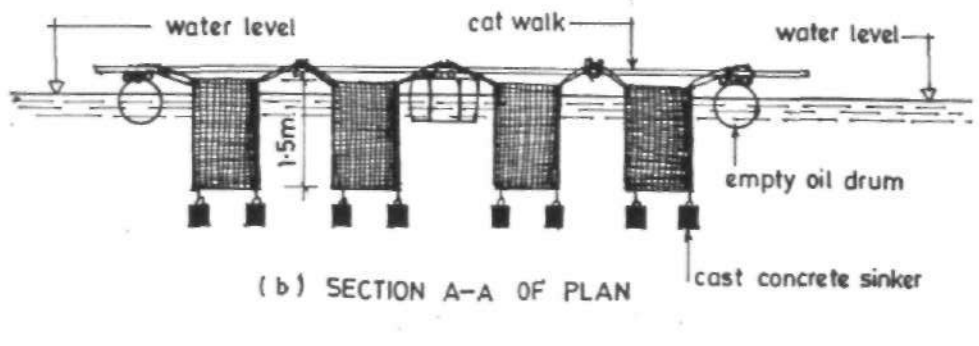
K— I-5m —H « - i-5m - - * «— I-5m-••-*•'•+ I • 5 m *

F-) FOUR. 2-PIECE UNIT 5 (1,2,3. 4 J JUX TA PO MED AND NA AT ALL THE 16 INTERSECTIONS TO OBTAIN '\ RAFT WITH I APARTMENTS.

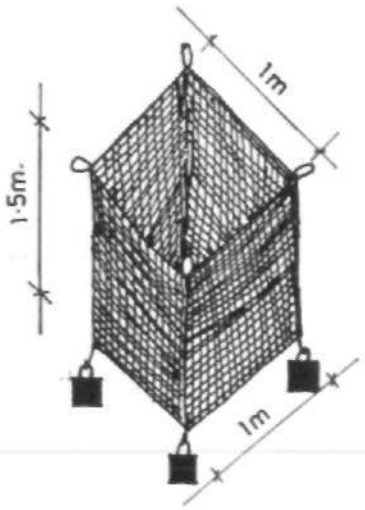
i



(a) PLAN



(b) SECTION A–A OF PLAN



(c) PERSPECTIVE VIEW OF A CAGE

Fig. 3·4 16 Units Bamboo Floating Cages
(NOT TO SCALE)



Plate III Bamboo Rafts being towed away to a cage culture site.

to prevent drowning in case of sudden rise in the water depth at the site as a result of flood.

3.3.2 Net - Hapa Design and Construction

The only net-hapa size that was used in all the hatchery/nursery-related experiments was the 1m x 1m x 1m design but had a net-cover at the top to prevent fish from jumping out (Plate IV).

The following materials were used in the design and construction of the net-hapa: roll of hapa netting (about 27m length per roll), nylon thread 210/2 and kuralon rope No. 10.

3.3.2.1 Procedure

(i) The roll of hapa netting was first cut into the desired sizes (say 1m x 1m) making up the six walls (four side walls, one at the bottom and the sixth at the top as cover) of the hapa to be constructed.

(ii) The six pieces (1m x 1m per piece) were then sewn together with the nylon thread (210/2) to form a six walled hapa, with a top cover, leaving an opening about 20cm at the top corner for stocking/retrieval and feeding of fish (Figure 3.5).

(iii) Kuralon rope No. 10 (four pieces about 2m length per piece) were finally sewn

to prevent drowning in case of sudden rise in the water depth at the site as a result of flood.

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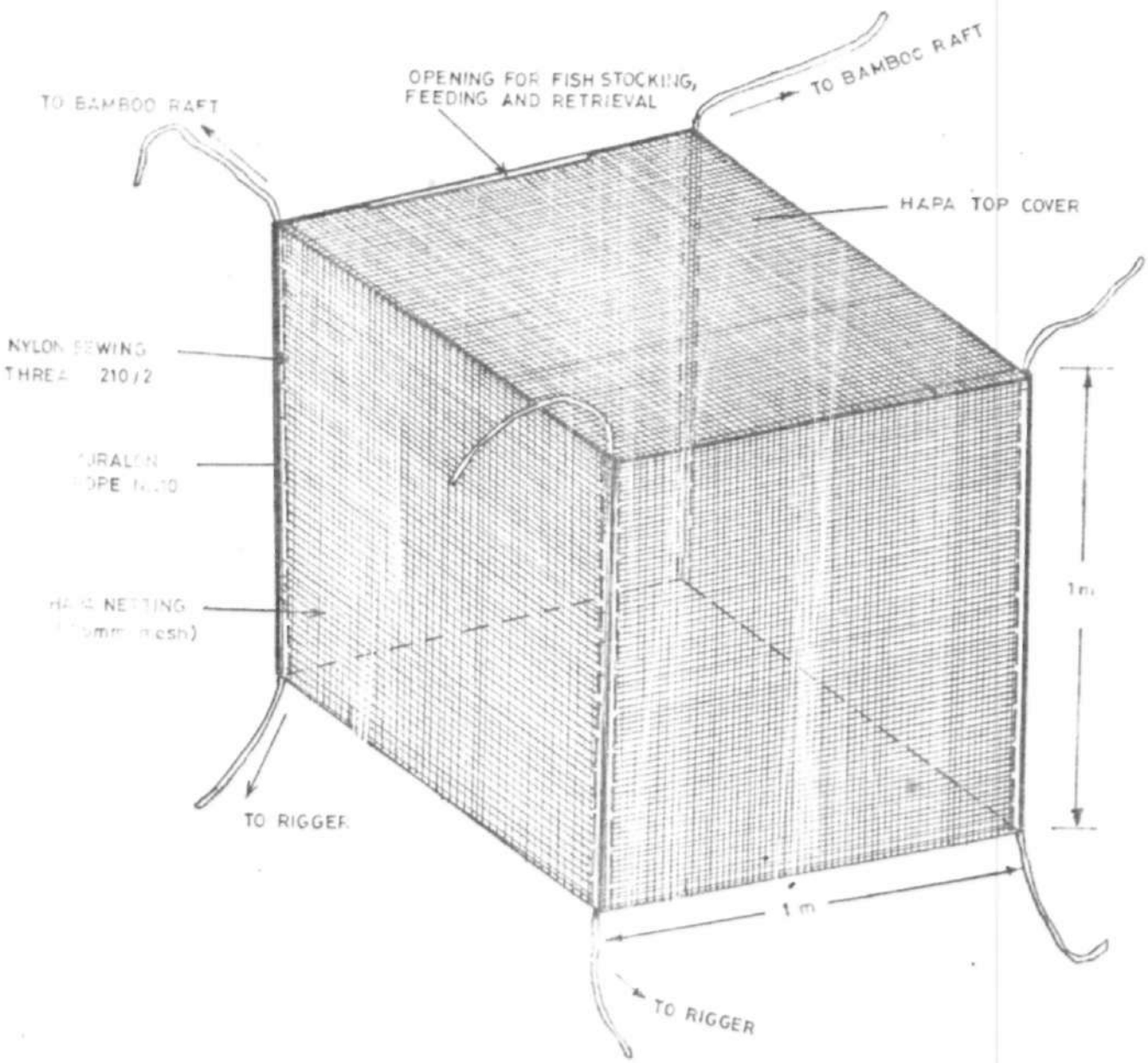


FIG. 3.5 NET HAPA (1m X 1m X 1m) USED FOR HATCHERY/ NURSERY RELATED ACTIVITIES.



Plate IV Hatchery/Nursery system showing

to reinforce the vertical corners of the hapa with 50cm of the Kuralon rope extending up and down for tying the hapa to the raft and tying of the riggers respectively (Figure 3.5).

3.3.3 Net-Cage Design and Construction

Four different sizes of net-cages were used during this study:

- 1m x 1m x 1.5m
- 2m x 2m x 2m
- 3m x 3m x 2.75m (Figure 3.6C)
- 3m x 3m x 3.5m

The mesh sizes of these cages varied from 10mm to 25mm depending on the size of fish to be stocked in the cage.

The materials needed for net-cage construction were: bundle of knotted net 210/9 400 M.D; mounting twine 210/21; kuralon rope No.15 (M.D. means Meshes Depth).

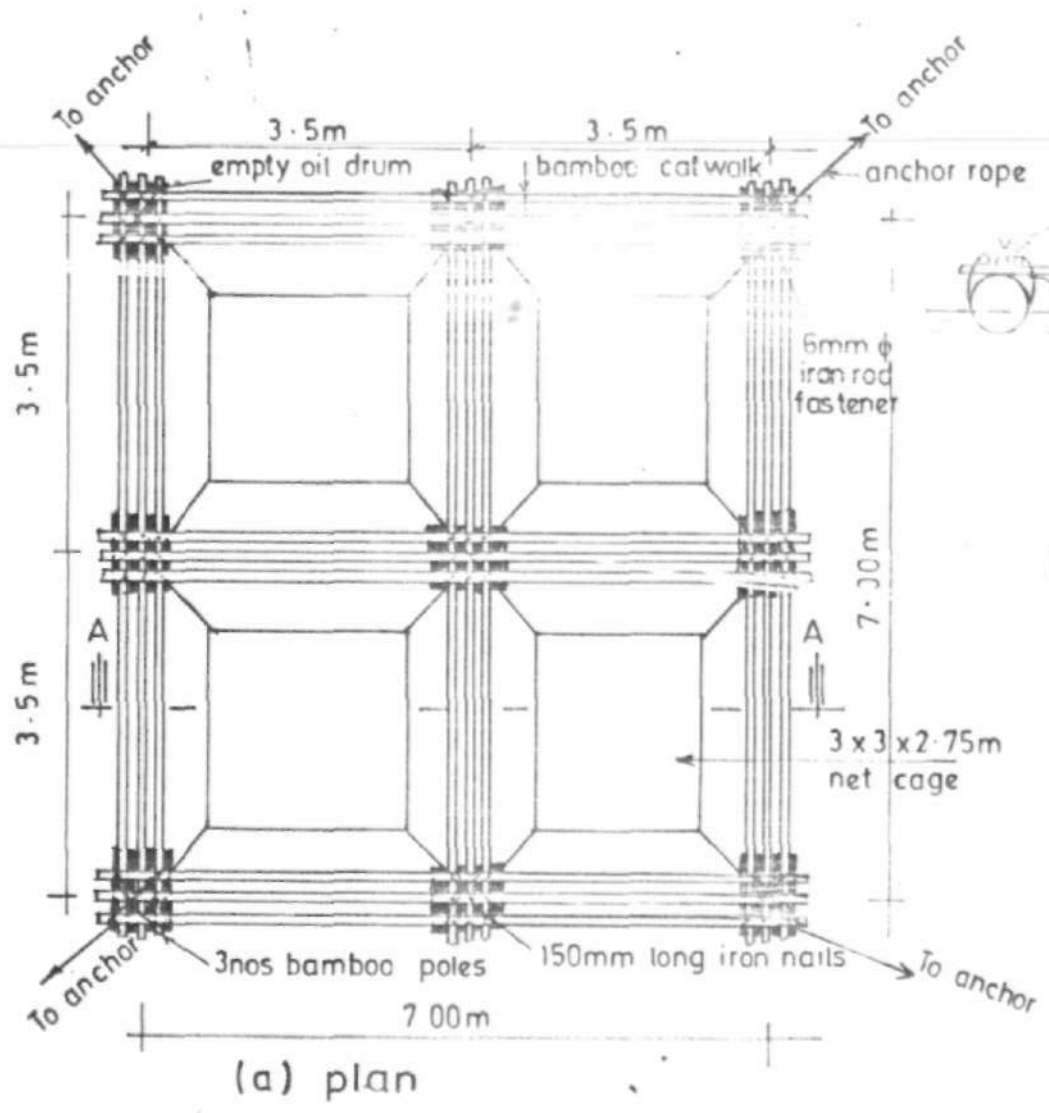
3.3.3.1 Procedure

(i) The kuralon rope No. 15 was stretched out overnight in order to make it taut.

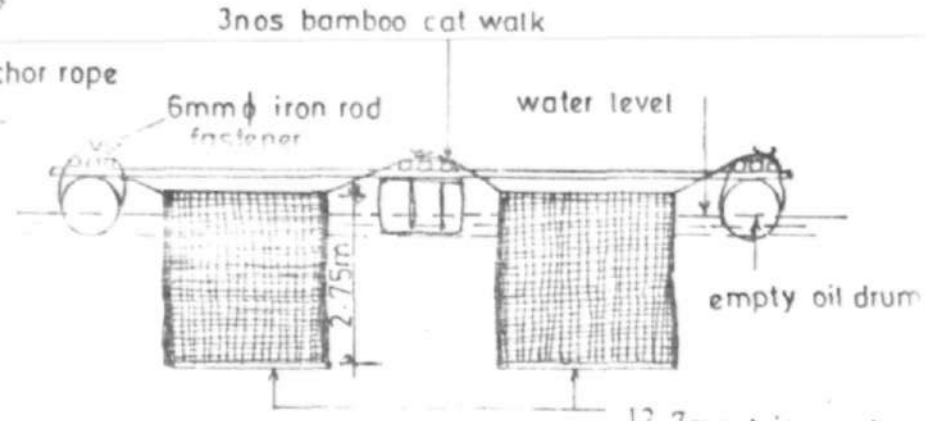
(ii) The knotted net was then mounted on the taut kuralon rope at 70% (Coefficient of horizontal hanging) using mounting twine fastened to a mounting needle.

$$\text{Coefficient of Horizontal Hanging (\%)} = \frac{\text{Length (in mm)}}{\text{Net mesh x No. of meshes size (in mm)}} \quad (3.1)$$

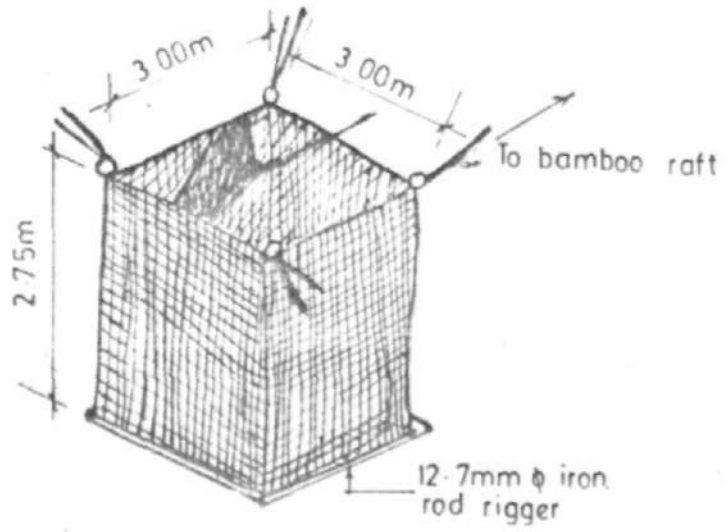
(FAO, 1978)



(a) plan



(b) section A-A of plan



(c) perspective view of a cage

Fig. 3·6 Layout, section and perspective view of a module of 4-unit (3x3x2·75m) net-cages.

(NOT TO SCALE)

For example:

At a mounting interval or length of 100mm (10cm), a net mesh-size of 19mm and 70% coefficient of horizontal hanging, eight meshes of the net will be mounted into the length of 100mm (Figure 3.7) (Plate V).

(iii) The net was mounted according to the desired dimensions of the cage, leaving loops of kuralon rope No. 15 at all the eight corners of the cage for tying the cage to the bamboo raft at the top and the concrete riggers at the bottom corners to expand the cage (Plate VI).

(iv) The bottom of the cage was made of double wall as reinforcement while the top-lid was single walled. An opening of about 20cm was left at the top corner for stocking, retrieval and feeding of the fish stocked.

3.4 The experimental fish used

Nine fish species belonging to six families were used in the various experiments during the study (Table 3.1).

All these fish species are found in Lake Kainji and are among the commercial species in the lake. All the species except Alestes dentex and Distichodus rostratus have previously been cultured in ponds or reservoirs (Bardach et al., 1972). All these nine fish

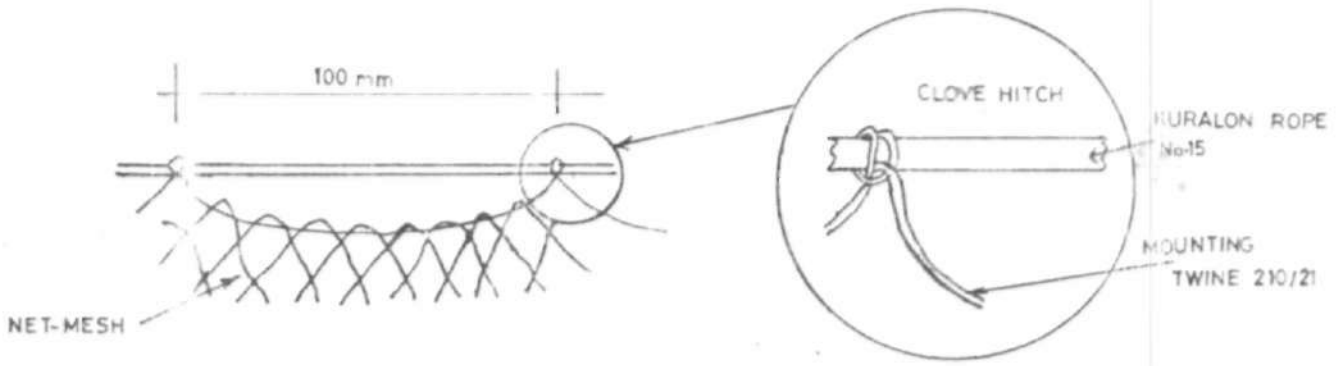


FIG. 3·7 MOUNTING OF NET-CAGE (19mm mesh) AT 70% COEFFICIENT OF HORIZONTAL HANGING ON KURALON ROPE No.15



Plate V Mounting net-cage at 70% hanging coefficient.



Plate VI Net-Cage (3m x 3m x 2.75m) with
riggers at the four bottom corners.

Table 3.2 The family and species of fish used.

Family	Species
CICHLIDAE	Sarotherodon galilaeus (Linnacus)
	Oreochromis niloticus (Linnaeus)
	Tilapia zillii Gervais
CHARACIDAE	Alestes dentex (Cuvier & Valenciennes)
CLARIIDAE	Clarias gariepinus Cuvier & Valenciennes
	Heterobranchus bidorsalis Geoffroy St. Hilaire
CITHARINIDAE	Citharinus citharus (Geoffroy St. Hilaire)
DISTICHODONTIDAE	Distichodus rostratus Gunther
CENTROPOMIDAE	Lates niloticus (Linnaeus)

species were used during the preliminary cage culture trial in order to test their cage-culturability. But only the tilapias (Oreochromis niloticus and Sarotherodon galilaeus) were consistently used throughout the remaining experiments since their fingerlings were readily produced under captivity, even under cage (net-hapa) culture system. Moreover, one of the main objectives of this study was to evolve a cage culture technology readily transferable to local fishermen, fish farmers and other interested individuals. Tilapia, therefore, was the best choice to start off with.

3.4.1 Characteristics of the fish species used

3.4.1.1 Sarotherodon galilaeus (Plate VII)

S. galilaeus is one of the best known species of genus Sarotherodon characterized by being biparental mouth brooders (Trewavas, 1982). S. galilaeus is a fairly large tilapia with a deep, strongly compressed body. The colouration is uniform olive with no obvious stripes or spots. The caudal fin is usually pinkish in colour along the distal border. S. galilaeus is readily distinguished from other species by its brush-like teeth and very fine, densely packed pharyngeal teeth. It has 15-16 spines in the dorsal fin. In the wild, S. galilaeus attains a length of 40cm and a

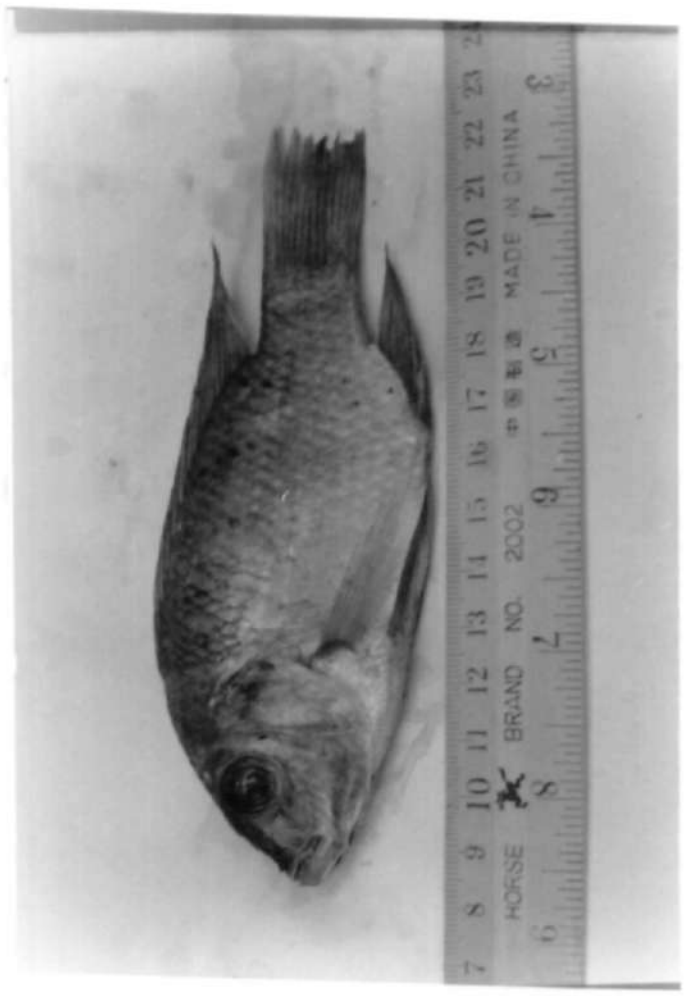


Plate VII Sarotherodon galilaeus

weight of over 1.5 kg. It feeds almost exclusively upon phytoplankton and algae (Akintunde, 1976). S. galilaeus is the most abundant cichlid in Lake Kainji (Johnson, 1974).

3.4.1.2 Oreochromis niloticus (Plate VIII)

This is the largest of the cichlids in Lake Kainji. In the wild, it attains a length of nearly 50cm and a weight of over 2 kg (Lewis, 1974). It is more elongate and less compressed than S. galilaeus. The colouration is brownish olive with faint dark vertical bars on the flanks. The posterior part of the dorsal fin, the caudal fin and the anal fin bear numerous dark vertical bars on a pale background, a characteristic which serves to distinguish it from all other species. O. niloticus has been described as a maternal mouth-breeding tilapia (Trewavas, 1982). O. niloticus has 17-18 spines in the dorsal fin. The pharyngeal teeth are numerous but not densely packed. The fish is mainly microphagous and it is the second most abundant cichlid in Lake Kainji (Johnson, 1974; Lewis, 1974).

3.4.1.3 Tilapia zillii (Plate IX)

This is a rather small species of tilapia rarely exceeding 25cm in length or 300g in weight (Lewis, 1974). The usual colour is greenish yellow with between 6 and 8 vertical dark olive stripes



Plate VIII *Oreochromis niloticus*

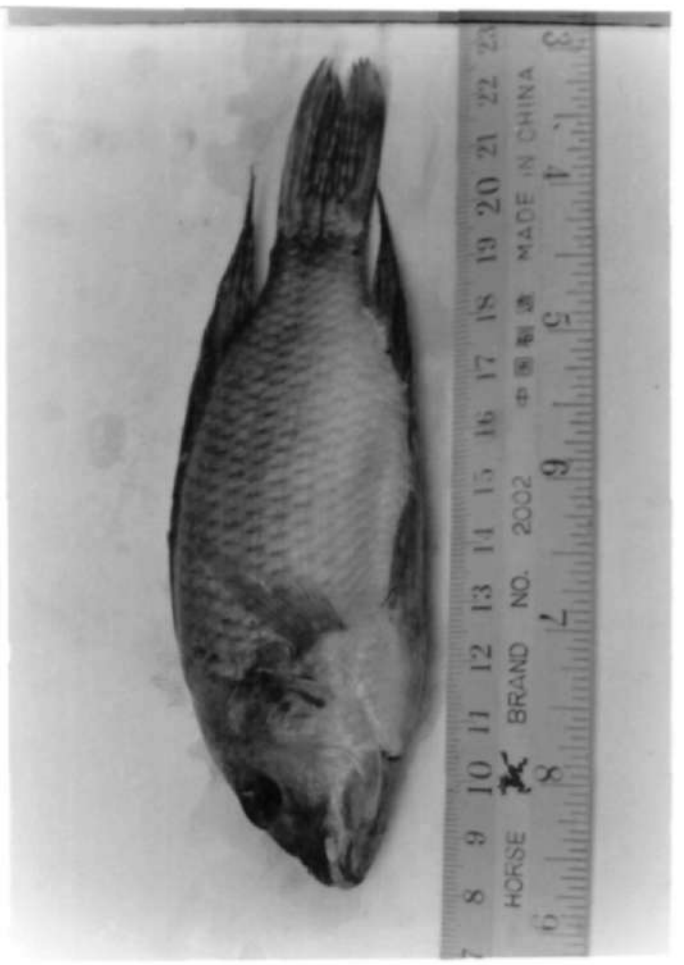


Plate IX Tilapia zillii

on each flank. Two dark horizontal bars are usually present on each flank, one running along the midline and the other between the midline and the dorsal fin. The posterior part of the dorsal fin, the caudal fin and the anal fin are marked with a red-brown or pink-grey network over a yellow background. The posterior margin of the caudal fin is distinctly rounded. The diet of T. zillii consists of insects and plant material (Lewis, 1974).

3.4.1.4 Alestes dentex (Plate X)

This is one of the larger members of the genus Alestes growing to a length of 45cm and a weight of 600g (Lewis, 1974). The body, which is compressed is uniformly silver in colour. The lower lobe of the caudal fin is red and the upper lobe grey with a tinge of red or orange. The anal fin is also invariably tinged with red or orange. A. dentex feeds to a large extent upon grasses though seeds and aquatic insects also feature in its diet (Bakare, 1968). This fish species is very common in Lake Kainji (Bakare, 1968).

3.4.1.5 Clarias gariepinus (Plate XI)

C. gariepinus is an elongate fish with a strongly depressed head and cylindrical body. The colour is variable though it is usually dark brown in colour and the dorsal and caudal fins are invariably very dark.



Plate X *Alestes dentex*



Plate XI Clarias gariepinus

In the wild, it grows to approximately one metre in length and 7 kg in weight (Lewis, 1974). C. gariepinus is a bottom dwelling species hence it is often referred to as mud catfish. It feeds upon small fish and carrion (Bakare, 1968). C. gariepinus possesses accessory breathing organs and can withstand conditions of low oxygenation. It is easily distinguished from C. anguillaris by its vomerine tooth band which is wider than the praemaxillary tooth band.

3.4.1.6 Heterobranchus bidorsalis (Plate XII)

This is a large elongate fish with a very wide strongly depressed head. It differs from Clarias spp in possessing an adipose fin. The colouration of the fish is brown to olive-grey and the fins are usually reddish-brown. It grows to a length of almost 1.5m and attains a weight of more than 30 kg (Lewis, 1974). H. bidorsalis is both a predator and a scavenger.

3.4.1.7 Citharinus citharus (Plate XIII)

C. citharus is a large laterally compressed, deep-bodied fish. The colour of the body is uniform silver and there are no stripes or other markings. The lower lobe of the caudal fin is deep red and the anal and pelvic fins tinged with red. The adipose fin is quite small and has a rounded outline.



Plate XII Heterobranchus bidorsalis

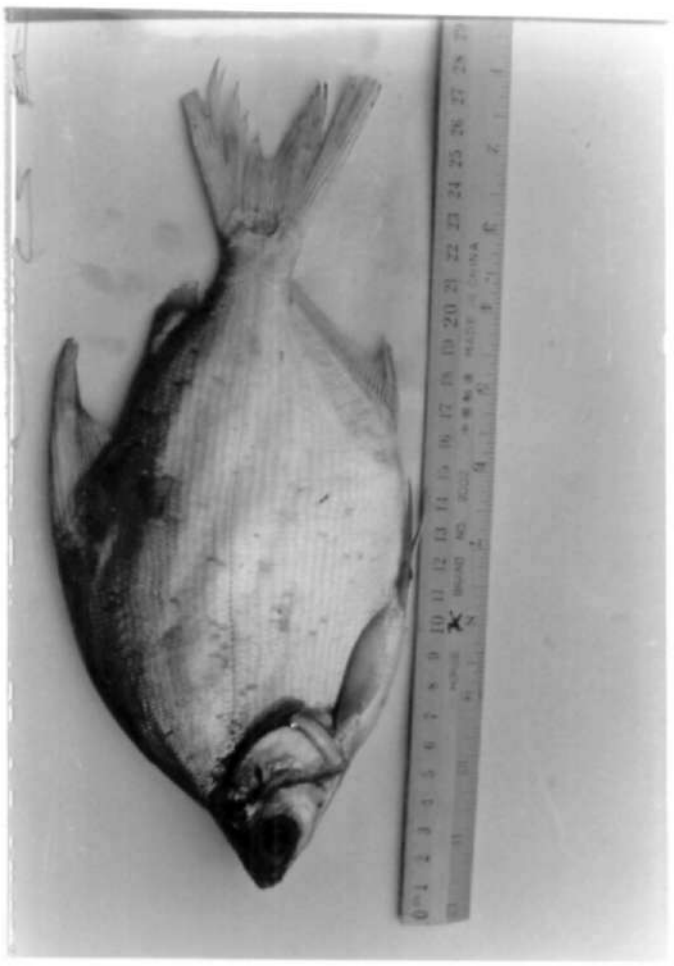


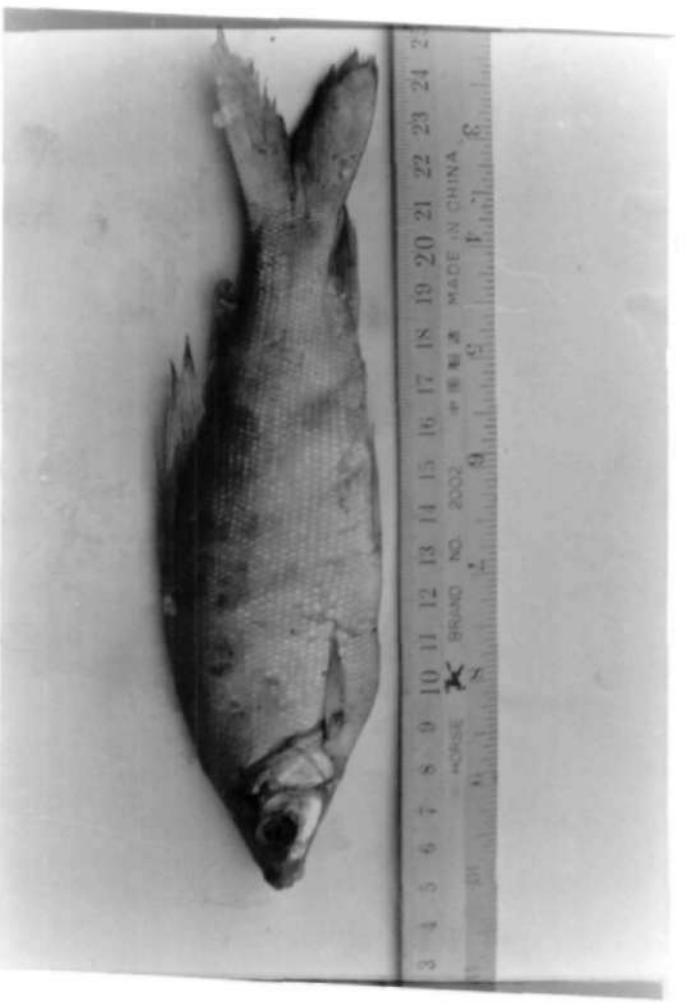
Plate XIII Citharinus citharus

In Lake Kainji, C. citharus grows to a length of 55cm and a weight of more than 3 kg (Lewis, 1974).

It is a shoaling species and at certain times of the year, large numbers may be seen splashing at the water surface. They are essentially bottom feeders and their diet consists almost exclusively of the algae which grows in the surface layers of the mud on the lakes floor (Bakare, 1968). C. citharus is by far the most common species of Citharinus occurring in Lake Kainji and during the early years of the lake's existence was the most important commercial species (Turner, 1971). C. citharus has 81 - 92 lateral line scales unlike the other Citharinus spp which have less number of lateral line scales (Lewis, 1974).

3.4.1.8 Distichodus rostratus (Plate XIV)

The colour of adults of this species is uniformly dull-grey though young individuals bear dark spots on the flanks. The snout is fairly round and the adipose fin is short. It has approximately 12 vertical blue-grey bars on each flank. These marks become less prominent with age. It grows to a length of more than 50cm and a weight of 2 kg (Lewis, 1974). D. rostratus is herbivorous and feeds to a large extent upon aquatic grasses (Arawomo, 1972). The mouth is sub-terminal.



Plates XIV Distichodus rostratus

3.4.1.9 Lates niloticus (plate XV)

L. niloticus often referred to as Niger or Nile perch is one of the largest freshwater fish in Nigeria.. It is a giant predatory species which attains a weight of more than 100 kg (Lewis, 1974). The body is laterally compressed and quite deep, larger specimens being more heavily built than small specimens. The adult colour is uniform steel grey. The diet of adults consists entirely of fish, though insect larvae and nymphs form an important part of the diet of juveniles (Balogun, 1988).

3.5 Feed mill and fish feed preparation

Most of the feeds used under the different feeding experiments in this study were prepared at the mini feed mill at National Institute for Freshwater Fisheries Research (NIFFR), New Bussa. The feed mill has two machines - one for fine grinding of feed ingredients and the other a pepper grinder modified by incorporating an appropriate set of dies for extruding moist pellets. Mixing of feed ingredients at the mini feed mill was manual. The finely ground and sieved feed ingredients having been weighed and mixed together according to the feed composition were moistened with hot water (for better pelletability) into a dough and then fed into the receiving receptacle of the improvised pelleting machine. A wooden stick

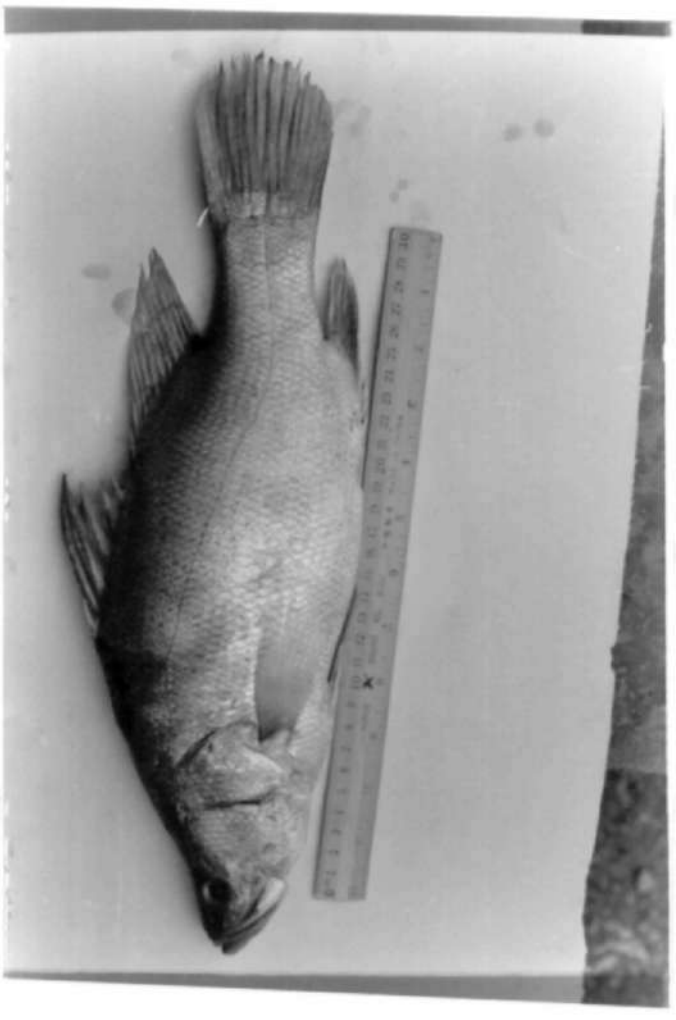


Plate XV Lates niloticus

was then used to force down the dough in the receptable of the machine for extrusion into pellets.
The wet pellets were air-dried within the feed mill space at room temperature about 28°C and packed for feeding.

3.6 Fish feed proximate composition determination

Proximate analysis is the most generally used chemical scheme for describing feedstuffs and it has been the key to determining the useful digestible or metabolizable energy of a feed. This analysis, devised by workers at the Weende Experimental Station in Germany (Crampton and Harris, 1969) partitions a feedstuff or feed into six fractions: moisture, ether extract, crude fibre, nitrogen-free extract, crude protein and ash. The sum of crude fibre and nitrogen-free extract represents total carbohydrate. These parameters were determined using standard methods (Association of Official Analytical Chemists, AOAC, 1980).

3.6.1 Moisture

The determination of moisture is one of the most important and widely used analytical measurements. Moisture content is frequently used as an index of stability and quality as well as a measure of yield and quantity.

3.6.1.1 Procedure

A known weight of the ground sample was oven dried at a temperature of 100 - 105°C until constant weight was obtained (about 24 hours). The loss in weight of the sample represented the moisture content (Lovell, 1975).

3.6.1.2 Calculation

$$\% \text{ Moisture} = \frac{WO - WD}{WO} \times 100 \qquad (3.2)$$

Where WO = weight of original sample

WD = Weight of dried sample.

3.6.2 Crude protein

The Kjeldahl method estimated the tota nitrogen which was converted to total crude protein by means of an empirical factor, usually 6.25, which depended on the proportions of the various nitrogenous compounds present in a particular sample.

Crude protein determination was modified from microkjeldahl method (AOAC, 1980) and consisted of three major steps viz. digestion, distillation and titration. The chemistry of the steps involved the digestion of protein with concentrated sulphuric acid in the presence of a catalyst (copper sulphate pentahydrate and potassium sulphate) and the nitrogen was converted to ammonium sulphate. Addition of an excess strong sodium hydroxide to the resulting solution

liberated ammonia which was then passed into an absorbing agent, boric acid and finally titrated with standard hydrochloric acid. (Crampton and Harris, 1969; Jacobs, 1973).

3.6.2.1 Procedure

50mg of the ground sample (3 - 5g) was weighed out into a crude filter paper (4.25cm diameter; 0.45µm pore size) and transferred wrapped in the filter paper into the Kjeldahl digestion flask. A Hengar granule, 2g digestion catalyst and 5ml concentrated sulphuric acid were added to the flask. The sample was digested in a digestion apparatus under the hood, rotating the flask regularly until the solution in the flask was clear (approximately two hours). The digest was partially cooled before adding 40ml ammonia-free distilled water.

10ml 4% boric acid was measured out into a 125ml Erlenmeyer flask, 4 drops bromocresol purple and methyl red indicator were added and the flask was connected to the tip of the condenser of the Kjeldahl distillation unit. 30ml 4% NaOH was rapidly added to the dissolved digest attached to the distillation unit. Distillation lasted for about 10 minutes or until the total volume of the receiving flask was doubled. The receiving flask was lowered free from the condenser and distillation was continued for 1 minute.

The distillate was titrated in the Erlenmeyer flask with standard hydrochloric acid solution until the solution turned from green to light pink end point. The volume of standard hydrochloric acid used for the tiltration was recorded.

3.6.2.2 Calculation

$$\% \text{ Nitrogen} = \frac{\text{Volume HCl (corrected)} \times \text{Normality HCl} \times 0.014}{\text{Weight of dry sample}} \quad (3.3)$$

$$\% \text{ Crude protein} = \% \text{ Nitrogen} \times 6.25 \quad (3.4)$$

N.B. A blank titration was run by using the same size of filter paper used to wrap the sample and equal quantity of digestion reagents. The volume of standard HCl used for titration of the blank was subtracted from the volume of standard HCl used for titration of the sample to get the corrected volume of HCl used for the titration of the sample.

3.6.3 Crude fat

Fat is reported as that substance which is insoluble in water, very slightly soluble in alcohol and soluble in organic solvents like carbon tetrachloride, carbon disulphide, anhydrous ether, or petroleum ether. Since small amounts of substances other than fat, like waxes, resins, chlorophylls and carotenoids, are included in the ether extract, the result is generally designated as "crude fat" or "ether extract".

The method involved wrapping the ground sample in filter paper and extracting the fat with enough anhydrous ether in a soxhlet apparatus. The excess ether was then evaporated and the residue dried to constant weight at 105°C (Maynard, 1970; Jacobs, 1973).

3.6.3.1 Procedure

2.00g sample was weighed in a Whatman filter paper No. 50, folded and wrapped with another piece of filter paper of the same size. The sample was placed in the extraction chamber of the soxhlet apparatus. The soxhlet flask was set up with enough anhydrous ether (approximately 175ml) in the flask. The fat was extracted for 10-12 hours. The sample was removed and air-dried to remove excess ether. The sample was reserved for crude fibre determination. The soxhlet flask was dried with the fat in the over at 105°C until constant weight. The weights of the flask and fat were recorded.

3.6.3.2 Calculation

$$\% \text{ Crude Fat} = \frac{\text{Corrected weight of fat}}{\text{Weight of original dry sample}} \times 100 \qquad (3.5)$$

N.B. A blank was run using the same size of filter paper. The weight obtained was subtracted from the weight of fat in the sample.

3.6.4 Crude fibre

Crude fibre is the washed, dried organic residue that remains after boiling the defatted material successively with dilute sulphuric acid and sodium hydroxide solutions. Crude fibre is commonly used as a measure of the nutritive value of feeds. The digestibility of crude fibre is low, thus, feeds with high crude fibre content are of low nutritive value.

3.6.4.1 Procedure

The defatted sample was transferred into a 600ml beaker (tall form). Boiling 0.64N sulphuric acid was added then one drop of antifoam compound. The resulting mixture was heated and allowed to boil for 10 minutes with constant shaking. The mixture was filtered immediately through dress linen. The residue on the filter was washed with boiling water until the washings were no longer acidic (washings turned red to yellow with methyl red indicator). The residue was returned into the beaker using approximately 100ml of hot distilled water in the transfer. It was made up to the 100ml mark with distilled water. Boiling 1.56N sodium hydroxide was added up to the 200ml mark. One drop of antifoam compound was added. The mixture was heated and allowed to boil for 10 minutes with constant shaking, then filtered immediately through dress linen. The residue on the

filter was washed with boiling water until the washings were no longer alkaline (washings turned pink to colourless with phenolpthalein indicator).

3.6.4.2 Calculation

$$\% \text{ Crude fibre} = \frac{\text{Weight of crucible 105°C - weight of crucible 550°C}}{\text{Weight of original dry sample}} \times 100 \quad (3.6)$$

3.6.5 Ash

When samples are heated to temperatures of 500° - 600°C, water and other volatile constituents are evolved as vapours and the organic substances are burned in air to carbon dioxide, oxides of nitrogen and water. The mineral constituents remain in the residue as oxides, sulphates, phosphates, silicates and chlorides depending on the conditions of incineration and the composition of the sample. This inorganic residue is called ash. It includes K, Na, Ca, and Mg which are present in larger amounts, as well as smaller quantities of Al, Fe, Cu, Mn, Zn, As, I, F and other elements present in trace amounts (Maynard, 1970).

The ash content was determined from the loss in weight after ignition of the sample at temperatures high enough to allow all organic matter to be oxidized without allowing appreciable decomposition of the ash or its loss by volatilization. Heating was continued until the resulting ash was uniformly white

or grey (occasional reddish or green) and free from particles of unburned carbon and fused lumps.

3.6.5.1 Procedure

A clean porcelain was heated in a muffle furnace at 550°C for about an hour and later cooled in a dessicator. 2.00g of the sample was weighed into the weighed crucible. The sample was pre-ashed under the hood until fumes were consumed. The crucible was transferred to a muffle furnace and ignited at 550°C for about 6 hours or until the residue was uniformly greyish to white. The temperature in the furnace was brought down to 105°C and maintained for 20 minutes. The residue was cooled in a dessicator and weighed after 30 minutes. The crucible was reheated in an oven at 105°C, allowed to cool then weighed. This operation was repeated until constant weight was obtained. The final weight of the crucible was recorded.

3.6.5.2 Calculation

$$\% \text{ Ash} = \frac{\text{Weight of the residue}}{\text{Weight of original dry sample}} \times 100 \qquad (3.7)$$

3.6.6 Nitrogen-Free Extract (NFE)

Nitrogen-free extract is a calculated feed fraction designed to estimate the highly digestible carbohydrates such as starch, free sugars and hemicellulose. It is the difference between the original weight of the sample and the sum of the weights of its

water (moisture), ether extract, crude protein, crude fibre and ash, as determined by their appropriate analysis. Nitrogen-free extract will also account for any lignin and cellulose not accounted for in the crude fibre (Kamstra, 1975).

3.6.6.1 Calculation

$$\% \text{ NFE (dry basis)} = 100 - (\% \text{ crude protein} + \% \text{ crude fat} + \% \text{ crude fibre} + \% \text{ ash}) \quad (3.8)$$

3.6.7 Minerals

Calcium, manganese, magnesium and iron contained in the feeds were analyzed using the ANA 180 Atomic Absorption Spectro-photometer.

The ash obtained from the 3.6.5.1 above was dissolved in 10ml dilute HCl. The solution was further diluted to 50ml using distilled water. The solution was aspirated into the air-acetylene flame. A hollow cathode lamp for the desired metal was installed in the instrument. Considering the different minerals, the instrument was set at a wave length of 422.7mu for calcium; 285.2mu for magnesium; 279.5mu for manganese and 248.3mu for iron. The spectro-photometer was standardized before each determination by using already prepared standard solutions of each element.

3.7 Growth determination and feed utilization indices

In this study, the parameters measured were growth and survival. Other parameters evaluated were feed conversion and feed efficiency.

3.7.1 Growth and survival rate

Growth, length, weight and survival are the most common indices for evaluating the efficiency of a feed. These parameters were calculated using the formulae below:

(a) Growth $= \frac{Wt - Wo}{t}$ (g per day) (3.9)

Where Wt = Average fish weight (g) at time t (days)

Wo = Average fish weight (g) at stocking

(b) Survival $= \frac{Nt - No}{No} \times 100\%$ (3.10)

Where Nt = Number of fish in the cage at time t (days)

No = Number of fish in the cage at stocking.

3.7.2 Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER)

The method of Castell and Tiews (1980) was used in the calculation of Feed Conversion Ratio.

(a) FCR $= \frac{\text{Wt. of feed consumed per unit of time}}{\text{Wt. gained by fish per unit of time}}$ (3.11)

N.B. This parameter is sometimes referred to as "absolute food quotient".

High values mean poor diets because large amounts of food are required to produce growth (g or kg) while low values indicate relatively small amounts needed per unit growth.

(b) Protein Efficiency Ratio was calculated using the method of Osborne et al. (1919)

$$PER = \frac{\text{Weight gain}}{\text{Crude Protein consumed}} \qquad (3.12)$$

3.8 Water quality determination

The water quality parameters studied involved broadly some aspects of the physical, chemical, and biological characteristics. The parameters included: temperature; hydrogen ion concentration (pH); primary productivity; dissolved oxygen; transparency; conductivity; turbidity and suspended solids. These parameters could adversely affect survival, growth and reproduction of fish. Standard methods of APHA (1966) of analyses were employed in the determination of these water quality parameters.

3.8.1 Temperature

Air temperature (ambient) as well as water temperature within each culture unit viz: net-cage or net-hapa, were measured in the mornings (07.30 - 08.30h) and evenings (17.30 - 18.30h) thrice a week, using the ordinary mercury-in-glass thermometer calibrated from 0°C to 60°C. The thermometer was

dipped direct into the water up to a depth of about 10cm for about 5 minutes and the temperature reading on the thermometer was noted.

3.8.2 Hydrogen ion concentration (pH)

pH of the water in each culture unit was measured once weekly using a Lovibond Comparator. Water sample from each culture unit (cage or hapa) was measured into a comparator glass tube. About ten drops of bromothymol-blue indicator were added to the water sample and shaken thoroughly. The sample to which the indicator was added was then compared with the sample with no indicator - placed side by side in the Lovibond Comparator. The disc was then adjusted until the colour of the two water samples in the comparator were similar. The pH of the water sample was then read off from the scale.

3.8.3 Dissolved Oxygen content

The water to be analyzed was siphoned into BOD bottle and allowed to overflow for a few minutes. The bottle was covered with care so as not to entrap any air bubbles. Using different pipettes, 2ml manganese sulphate solution was added followed by 2ml of alkali-iodide-azide solution (Winkler's reagent) below the liquid surface. It was stoppered carefully to avoid air bubbles. It was shaken and the precipitate was allowed to settle. 2ml concentrated sulphuric acid was added, stoppered and shaken well to

dissolve the precipitate and to distribute the iodine uniformly. 200ml of the solution was measured carefully into a 500ml Erlenmeyer flask and promptly titrated with standard solution (0.025N) sodium thiosulphate to a pale straw colour. About 1.5ml starch indicator was added and titration continued until the blue colour disappeared. The amount of titrant used was noted.

3.8.3.1 Computation

$$\text{D.O. (mg/l or ppm } O_2) = \frac{(\text{ml titrant}) \times (\text{NST}) \times (8000)}{\text{Actual volume of water sample}} \qquad (3.13)$$

Where NST = Normality of sodium thiosulphate

3.8.4 Transparency

The transparency was measured by using the Secchi disc. The depths of the water at which the disc just disappeared from sight while being lowered gradually into the water column and the depth at which it again reappeared while being brought up were recorded. The average of these two readings gave the transparency (m). The parameter was recorded weekly.

3.8.5 Turbidity and suspended solids

These two parameters were measured with the Varian 634 UV-visible spectrophotometer. The instrument was initially zeroed with distilled water in both the reference and sample cell holders. The water sample was then placed in the sample cell holder

and the turbidity (in FTU) was read at 450nm (nanometer) wavelength, while the suspended solids measurement (in mg/l) was read at a wavelength of 803nm.

3.8.6 Primary productivity

Primary productivity was measured by the light and dark bottle technique (APHA, 1971, Boyd, 1979). A water incubation bottle was wrapped with black polythene material (dark) to exclude light. At the same time, water from the same depth was collected using a Van Dorn water Sampler and placed into a plain (light) incubation bottle. The two bottles (dark and light) were suspended in water at the same depth and left for 4 hours after which the amounts of oxygen in each bottle were measured by Winkler's method (see section 3.8.3 for details). The difference between the oxygen concentration in both bottles gave the primary productivity, which was converted to mg $O_2/m^2/day$ to obtain the daily primary productivity (in mg $C/m^2/day$) using the method of Windberg (1971): mg $C/m^2/day$ = 0.375 x mg $O_2/m^2/day$. (3.14)

3.8.7 Conductivity

Conductivity was measured by ELE model conductivity meter. The measurements (in µmho/cm) were taken in situ at 25°C after calibration.

3.9 Data analysis

The data where appropriate were analyzed using Tandy 4000LX Computer (manufactured by Radio Shack, U.S.A.) at NIFFR Headquarters, New Bussa. The statistical methods used included: Analysis of Variance (ANOVA); Least significant Difference test (LSD); and Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1976).

3.10 Economic analysis

The economic analysis in this study was based on the total cost of all inputs leading to production at a given time (i.e. total cost of production) and the gross profit (less appropriate taxes) from the sales of fish harvest at a given time in the life of the production system. The profitability of the cage culture fish production system was then assessed based on Return On Investment (ROI).

$$ROI = \frac{\text{Total cost of production at time T}}{\text{Gross Profit (less taxes) at time T}} \quad (3.15)$$

(a) Total cost of production include costs of cage raft and net-cages or net-hapas, other construction materials; cost of fish seeds and feed and labour for construction, feeding, maintenance/repair of the cage culture system.

(b) Gross Profit = (TP - TR) - AT (TP - TR) (3.16)

Where TP = Total Production Cost

TR = Total Revenue

AT = Appropriate Tax (%).

CHAPTER 4

4.0 CAGE CULTURABILITY OF SOME COMMERCIALLY IMPORTANT FISH SPECIES IN LAKE KAINJI

4.1 INTRODUCTION

In Lake Kainji, a total of 97 different fish species have been caught using various types of fishing gear at numerous ecological zones of the lake (Lewis, 1974). Of all these fish species some have been recognized to be of commerciall importance (Otobo, 1978).

Most of these fish species have not been reported in cage culture system except Oreochromis niloticus (Guerrero, 1975, 1979, 1980; Ishak, 1985, Campbell, 1985), Clarias gariepinus (Ishak, 1985; Emeheld and Mbgemena, 1986) and Lates sp (Lates calcarifer) (Wong, 1982; Yaman, 1982). In Lake Kainji, Nigeria, Konikoff (1975) and Ita (1976) experimented on the cage culture of Tilapia (Oreochromis niloticus, Sarotherodon galilaeus and Tilapia zilliii).

In species selection for cage culture, most of the fish species are expected to satisfy in part some of the requirements (e.g. fast growth, adaptability to crowding, ease of culture or management) listed under section 2.5.2. The use of the three species of tilapias at Lake Kainji by Konikoff (1975) and Ita (1976) further confirmed that Tilapia fulfils all

these requirements as earlier reported by Mane (1979), Coche (1982), Guerrero (1983) and Ishak (1985). Since one of the general aims and objectives of these studies is to provide information on the potential of some readily, locally available and commercially important fish species around Lake Kainji in cage culture system, the following experiments were carried out.

4.2 MATERIALS AND METHODS

4.2.1 The Fish

The fish species used in the experiments were silversides (*Alestes dentex*), grass eater (*Distichodus rostratus*), mormyrids (*Citharinus citharus*), cat fishes (*Clarias gariepinus* and *Heterobranchus bidorsalis*), tilapias (*Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zillii*) and Nile perch (*Lates niloticus*). The characteristics of all these nine fish species have been described under section 3.4.

4.2.2 The Sites

Two sites, Shagunu Bay located on the West of the middle basin of Lake Kainji and Kigera III Reservoir (a drinking water reservoir) situated within NIFFR Housing Estate at New Bussa (Figure 3.1) were used for these experiments. These sites have been described under section 3.2.

4.2.3 Cage Construction

A module of 9m x 9m bamboo raft with nine, 3m x 3m compartments fittable with 2m x 2m x 2m net-cages was used for the experiments both at Shagunu Bay and Kigera III Reservoir. The construction procedures are as described under sections 3.3.1 and 3.3.3.

4.2.4 The Culture Studies

4.2.4.1 Growth performance and Cage Culturability of mixed species locally available in Lake Kainji

Mixed species made up of all the nine fish species (listed under section 4.2.1) with mean weights ranging from 14.3g to 35.0g were stocked in a net-cage, 2m x 2m x 2m at Shagunu Bay in order to observe their growth performance and cage culturability. The stocking density of each fish species ranged from 5 to 20. Total number of the mixed species stocked in the cage was 140. The fish were fed once a week with 25% blood meal in pelleted feed (Feed I) having a crude protein content of 46.8% (Tables 4.1 and 4.2) but were made to subsist mainly on the natural food present in the cage environment. The feed was prepared as described under section 3.5. The proximate composition determination of the feeds (I and II) were carried out as described under section 3.6. The fish were sampled monthly for growth during the 150-day culture period (16 May - 12 October, 1986).

Table 4.1 Composition of two feed formulations fed to the fish under the mixed culture experiments.

Ingredient	Feed (%)	
	I	II
Blood meal	25	10
Corn bran/Layer's concentrates (ratio 3:1)	74	89
Vitamin premix[a]	1	1

[a] A premix used in poultry feed manufacture; contains oxytetracycline HCl, Vitamins A, D_3, E, K, B_2 and B_{12}, nicotinamide, calcium-d-pantothenate and antioxidant BHT.

4.2.4.2 Preliminary study on the growth of C. citharus in floating cages at two different sites

The two sites (Shagunu Bay and Kigera III Reservoir) were used for this experiment. C. citharus (mean weight, 7o.0g) were stocked at 50 fish per cage (2m x 2m x 2m) at Shagunu Bay, while C. citharus (mean weight, 58.0g) were also stocked at 50 fish per cage (2m x 2m x 2m) at Kigera III Reservoir. At both sites, the fish were fed once a week with 10% blood meal in pelleted feed (Feed II) with crude protein content of 31.3% (Tables 4.1 and 4.2). The feed was prepared as described under section 3.5. The fish were sampled monthly for growth during the 150-day culture period (December 1987 - 4 May 1988).

4.3 RESULTS

4.3.1 Growth performance of mixed fish species

Table 4.2 gives the results of the proximate analysis of the feeds. Table 4.3 shows the growth performances of the mixed fish species stocked in net-cages at Shagunu bay. C. citharus recorded the highest average growth rate (3.31g/fish/day), followed by C. gariepinus (3.28), O. niloticus (2.83), S. galilaeus (2.03), D. rostratus (1.02) and least in A dentex (0.25). Growth record was not obtained for the piscivore, L. niloticus because they all died before the first sampling period (less than 1 month of culture).

Table 4.2 Proximate analysis of the feeds

Feed	Crude Protein	Crude Fat	Crude Fibre	Ash	NFE	Ca	P
I	46.87	0.25	3.71	6.81	42.36	1.36	0.11
II	31.34	1.26	4.14	5.90	57.36	1.30	0.10

Table 4.3 Growth performance of mixed fish species stocked in floating cages at Shagunu Bay Lake Kainji for 5 months.

Species	No. Stocked	IFB (g)	Mean weight (g)		Average growth (g/fish/d)	
			Initial	Final		
C. cithaeus	10	540	54.0	550.0	3.31	Fast growth
O. niloticus	20	1 000	50.0	475.0	2.83	
C. gariepinus	5	675	135.0	627.0	3.28	
S. galilaeus	20	600	30.0	335.0	2.03	
H. bidorsalis	20	836	41.8	110.0	0.46	
T. zillii	20	286	14.3	77.3	0.42	-> Slow growth
A. dentex	20	1 200	60.0	97.5	0.25	
D. rostratus	20	400	20.0	173.0	1.02	-> Moderate growth
*L. niloticus	5	150	30.0	-	-	

* All died before first sampling (i.e. before end of 1st month of culture). I.F.B.: Biomass at stocking per fish species, Total (TIFB) = 5687g (i.e. total biomass of all fish stocked in the cage).

4.3.2 Growth performance of C. citharus (mono-culture) in floating cages at two different ecological sites

Table 4.4 gives the summary of the growth of C. citharus in mono-culture at Shagunu Bay and Kigera III Reservoir. Even though in this experiment C. citharus recorded a higher growth at Shagunu Bay than at Kigera III Reservoir, the growth of C. citharus in the mixed species experiment (at Shagunu Bay) was higher than in the mono-culture at Shagunu Bay. It was noted that the total initial fish biomass (TIFB) were 5.687 kg, 3.750 kg and 2.915 kg/cage for mixed species and mono-culture at Shagunu Bay and mono-culture experiment at Kigera III Reservoir respectively (Tables 4.3 and 4.4).

4.4 DISCUSSION

4.4.1 Growth performances of mixed fish species

Cage culture of mixed fish species have been reported in a few countries: In Indonesia, 10 to 25% O. niloticus was cultured as a secondary crop to Cyprinus carpio. de la Cruz (1979) also reported the mixed culture of hybrid tilapia and C. carpio in an experimental cage in Taiwan. He noted that the growth of the tilapias was very good, such that the local fish farmers since then prefer tilapias to C. carpio for cage culture. In Hungary, experiments were carried out in the cage polyculture of common carp

Table 4.4 Growth performance of C. alburnus (mono-culture) in floating cages at two culture sites.

Site	No. Stocked	TIFB (g)	Mean Weight (g) Initial	Final	Average growth (g/fish/d)
Shagunu Bay	50	3750	75.0	363.0	1.92
Kigera III Reservoir	50	2915	58.3	193.3	0.90

IFB: Biomass at stocking per fish species

TIFB: Total biomass at stocking of all fish in cage per culture site.

(C. carpio), grass carp (Ctenopharyngodon idella), silver carp (Hypophthalmichthys molitrix) and big head (H. nobilis). Muller (1979) reported that these fish species adapted themselves well to the conditions in the cages. All the fish species (except L. niloticus) used in the Shagunu Bay mixed culture survived and grew in the net-cage throughout the culture period.

Animal (including fish) growth rate, Bowen (1982) noted is determined through the combined effects of quantity and food quality. He further stressed that the food quality of a given food (or feed) is directly proportional to its ability to support growth. The natural food coupled with the sparingly feeding with supplementary feed must have contributed to the growth and survival of all the mixed fish species except L. niloticus. On post mortem examination, the stomachs of the L. niloticus were found to be empty. This is not surprising because Balogun (1988) observed that juveniles of L. niloticus (average weight, 100g) fed with pelleted blood meal feed in concrete tanks did not accept the feed for a whole month. He, however observed that when juveniles of tilapia were introduced into the tank, L. niloticus made swift and sudden dash at the prey after visual recognition and swallowed the prey whole. In Lake Volta, Petr (1967) reported that fish constituted over 99% of the total food of L. niloticus while in Lake Kainji, Ita (1978) described L. niloticus as an obligate carnivore. Invariably,

the other fish species stocked in the cage were too big as prey for L. niloticus to swallow. On the other hand, perhaps, it is possible that L. niloticus which is known to be a very active fish (Reed et al., 1967) could not adapt to confinement in the cage.

The planktivorous fish species which often have low protein requirements were mostly favoured in the mixed culture study. It was reported that the diets of tilapias (for example) range from about 50% to less than 1% protein and values below 15% are most common (Boyd and Goodyear, 1971; Caulton, 1978; Bowen, 1979, 1980a, 1980b). It was therefore, not surprising that the microphagous/planktivorous C. citrarus, O. niloticus and S. galilaeus recorded high growth rates. Algal growth was observed on the side walls and top cover of the cage. Occasionally, schools of clupeids (freshwater sardines) were found inside the cage during sampling periods. C. gariepinus has been described as omnivorous by Welman (1948); Reed et al. (1967); Imevbore and Bakare (1970); Carreon et al. (1973); Lewis (1974); Bard et al. (1976); Ejike et al. (1982), Olatunde (1983) and with a propensity for being carnivorous (Bard et al., 1976). C. gariepinus being an opportunistic feeder could have taken advantage of the various natural food (including clupeids) that came its way thereby recording the second highest growth rate. The macrophagous T. zillii, however, did not grow as fast as the other tilapias

(O. niloticus and S. galilaeus). In fact, T. zillii has been described to have the least growth rate of the three tilapias by Lewis (1974). T. zillii rarely exceeded 300g in weight in the wild whereas O. niloticus and S. galilaeus could grow to over 2 kg and 1.5 kg respectively (Lewis, 1974). Konikoff (1975) also observed that T. zillii is not attractive for cage culture not only because it is smaller than the other tilapias but it is also highly pugnacious (even under monoculture). Konikoff (1975) however, recommended the following as desirable for cage culture: O. niloticus, S. galilaeus, Clarias sp, H. bidorsalis, Bagrus sp. and C. citharus.

C. citharus (with no previous record of use in cage culture) surprisingly survived and grew well in floating cages. The good performance has therefore confirmed the observation of Arawomo (1972) that Citharinus sp were no longer bottom dwellers in Lake Kainji. In fact, all the C. citharus used in stocking the cage were caught by cast-netting around Shagunu Bay. The fish were, on some occasions observed to browse on the periphyton that grew on the cage walls. The growth rate of C. citharus in this study was higher than that of the pond system in Nigeria where C. citharus grew up to 500g in one year (Bardach, 1972). Imevbore (1970) and Arawomo (1972) observed that Citharinus spp are more fecund (range 161,840 to 684,500) than all other fish species inhabiting the

River Niger system. Hitherto, tilapias have been identified and have been in use in cage culture in several tropical countries of Africa, Asia and Latin America (ADCP, 1978; Coche, 1979; ADCP, 1982) both on a commercial scale and as subsistence fish culture for local people. C. citharus seems a potential candidate fish for cage culture considering its growth performance, fecundity, adaptability, late maturity (unlike tilapias), feeding at the base of the food chain and especially if there occurs a breakthrough in its induced breeding (for mass production of the fingerlings).

4.4.2 Growth Performance of C. citharus (mono-culture) in floating cages at two different ecological sites

In spite of the fact that the total potential fish biomass (TIFB) at Shagunu Bay mixed species culture was about 1½ times and 2 times the mono-culture at Shagunu Bay and Kigera III reservoir respectively, the growth of C. citharus (under mixed species culture) at the highest TIFB (5.68 kg/cage) was highest (3.31g per day) but lowest (0.90g per day) at the lowest TIFB (2.915 kg). At Shagunu Bay, the season of culture can be the cause of the differential growth of C. citharus under mixed species and mono-culture. For example, the culture period during the mixed species culture coincided with the period of algal bloom in Lake Kainji which peaks during the month

of October (Adeniji, 1973). This situation is corroborated by Coche (1982) who reported that dense plankton blooms produce much higher fish biomasses. Similar observations were also made by Armbrester (1972) and Suwanasart (1972) in the cage culture of S. aureus in fertilized ponds (with dense plankton population) in Alabama, U.S.A. without supplementary feeding. Warren (1971) reported that growth as a response to the integrated activities of an organism as a whole, is a sensitive parameter of the environment. This further corroborates the growth differential between C. citharus cultured at different seasons at Shagunu Bay and also the lower growth rate (0.90g/d) observed at Kigera III Reservoir. Plankton production has already been reported to be relatively low in this reservoir (Kigera) (Akinbweyere, 1990).

4.5 CONCLUSION AND RECOMMENDATION

In this mixed species culture experiment, it could be concluded that the tilapias (O. niloticus and S. galilaeus), catfish (C. gariepinus) and moonfish (C. citharus) are fast growers. These species are therefore, in popular use for aquaculture.

In the monoculture experiments, it is concluded that the nature of the environment (especially the abundance of natural food) affected the growth of C. citharus at the two culture sites.

Since the tilapias (especially O. niloticus) have been consistently used in cage culture (Coche, 1992), the good performance they had in the mixed species experiment has further confirmed their suitability for cage culture. H. bidorsalis, even though well known as a fast grower in the pond system was concluded unsuitable for cage culture system at the level of management used in the experiment. But C. citharus (with no previous record in cage culture) appeared to hold great promise in large scale culture in cages considering the strikingly good qualities of the fish (Reed et al., 1967; Motwani and Kanwai, 1970; Turner, 1971).

C. citharus is therefore, recommended as an additional indigenous fish species for cage culture even at large scale commercial level in floating cages. The fingerlings of the fish can be collected from the wild since large numbers of its fingerlings

are often seen splashing at the water surface. But considering the seasonality in the natural mass spawning of this fish species (Ita, 1980), it is further recommended that efforts be geared towards its artificial or natural induced breeding for mass fingerlings production.

CHAPTER 5

5.0 FEEDING EXPERIMENTS USING AGRO-INDUSTRIAL WASTES AND SOME OTHER FEEDSTUFFS (IN DIFFERENT COMBINATIONS) IN FLOATING CAGES

5.1 INTRODUCTION

Adequate feeding is essential for fish growth and survival in cages. In some cases, natural food (plankton, aufwuchs or benthos) may be sufficient and no supplementary feeding is required. When natural food is insufficient but still an important part of the diet, supplementary feeding is practised with relatively low-cost ingredients. Under intensive rearing conditions at high stocking densities, the natural food available for the cage fish becomes inadequate and a complete efficient artificial food is required.

Lack of nutritionally adequate and low-cost feed has always has been one of the constraints to the successful practice of cage fish culture in many developing countries. Coche (1978, 1979) observed that cost of feeding in intensive cage culture can account for more than 50% of the production costs. According to data published by Aquaculture Development and Coordination Programme (ADCP, 1983) it was further confirmed that feed represents 40 - 60% of the total operating costs in intensive aquaculture. However, in order for the venture to be profitable, ADCP (1983)

recommended that feed costs do not exceed 20% of the farm gate value of the fish. Weatherley and Cogger (1977) reported that a principal economic obstacle in culture of fish is the cost of protein in culture diets.

In considering feedstuffs for use in fish feeds, therefore, much concentration will be on agricultural, industrial and other forms of wastes otherwise seriously uncompeted for by any other animal or even man. Since one of the general objectives of the cage culture studies is to determine the effect of supplementary feeding on the survival, growth and production of fish in the cage culture system, series of feeding experiments using O. niloticus were carried out. A systematic approach was adopted in the evaluation of readily available agro-industrial bye-products towards formulation of practical feeds for fish production in cages. Since fish meal is keenly competed for by humans aside from the cost, feeding fish to fish especially under a large scale commercial aquaculture system could therefore be uneconomical. In some of the experiments, attempts were made to test the effect of some other protein sources like soyabean meal, blood meal and groundnut cake in supplementary feeds compared with a commercial feed on fish production in floating cages.

5.2 MATERIALS AND METHODS

5.2.1 The Effect of Different Feedstuffs on Tilapia fingerlings production in floating net-hapas

The experiment was carried out at Kigera III Reservoir (Figure 3.1) already described under section 3.2. A module consisting of a 6m x 6m raft with 16, 1.5m x 1.5m apartments fittable with 1m x 1m hapas was used. The construction procedures are as described under section 3.3.1.2 and 3.3.2.1. The experiment consisted of four treatments: I. Brewer's waste only; II. Rice bran only; III. Corn bran only; IV. Control (no feeding). Each treatment was replicated in three net-hapas using a completely randomized design. The fr of *O. niloticus* (mean weight 0.34g) were stocked at the rate of 100/m³ in all the hapas early morning. The try were fed twice daily (09.00 and 16.00h), seven days per week at the rate of 20% of their biomass per day. 30% of the stock was sampled every two weeks for growth. The fish were harvested after 42 days culture period (15 March - 25 April, 1986).

5.2.2 The Effect of different combinations of industrial and agricultural wastes as supplementary feeds on tilapia fingerlings production in floating net-hapas

The experiment was carried out at Kigera III Reservoir (Figure 3.1). A module consisting of a 6m x 6m raft with 16, 1.5m x 1.5m apartments fittable

with 1m x 1m hapas was used. The construction procedures are as described under section 3.3.1.2 and 3.3.2.1. The feedstuffs: corn bran, rice bran and brewer's waste (all in powder form) were combined according to the following treatments:

Treatment I - Corn bran only

Treatment II - Corn bran + Rice bran (1:1)

Treatment III - Corn bran + Rice bran + Brewer's waste (1:1:1).

Each treatment was replicated twice in a completely randomized design. The fry of C. nilotic s (mean weight 0.04g) were stocked at the rate of 100/m² in all the net-hapas early morning. The fis were fed twice daily (09.00 and 16.00h) at the ra of 20% of their biomass per day. Sampl ng for fis growth was done every two week by rando ly scoopin out 30% of the total stock per hapa. The fish w harvested after 42 days culture period 9 March - 9 May, 1987).

5.2.3 The effect of different agro-industrial wastes (adde to constant amount of fish meal) on Til pia finger lings produc tion in floating et-hapas

Kigera III Re ervoir (Figure 3.1) was the site used for the exper ment. A module consisting of a 6m x 6m raft with 16, 1.5m x 1.5m apartments fittable with 1m x 1m hapas was used. The construction procedures are as described under sections 3.3.1.2 and 3.3.2.1. The feedstuffs (in powder form): corn bran (CB), rice bran (RB) and brewer's waste (BW) were combined with

constant amount of fish meal (FM) also in powder form, according to the following treatments:

Treatment I - 74% CB + 1% premix + 25.0% FM

Treatment II - 74% RB + 1% premix + 25.0% FM

Treatment III - 74% BW + 1% premix + 25.0% FM

Treatment IV - 74% CB:RB:BW (in ratio 1:1:1) + 1% premix + 25.0% FM.

(Composition of premix is as given in Table 4.1). Each treatment was replicated twice in a completely randomized design. The fry (mean weight, 0.07g) were stocked at the rate of 100/m³ in all the hapas early morning. They were fed twice daily (09.00 and 16.00h) at the rate of 20% of their biomass per day. Fish in each hapa were sampled every two weeks for growth by scooping out 30% of the total stock per hapa. The weighing was done using sensitive analytical balance (Bosch type P115, 0.001g per calibration) in the laboratory. The fish were harvested after 42 days culture period (18 February - 30 March, 1988).

5.2.4 The Effect of varying levels of blood meal feeds on Tilapia production in floating net-cages

The experiment was carried out at Kigera III Reservoir (Figure 3.1). A module of 9m x 6m bamboo raft with six, 3m x 3m apartments to which were attached six units of 1m x 1m x 1.5m net-cages (210D/9, 10mm mesh size) was used for the feeding experiment. The construction procedures for the bamboo

raft and net-cages are as described under sections 3.3.1.2 and 3.3.3 respectively.

The composition of the three feeds tested is shown in Table 5.1 The moist pellets, produced by using a modified pepper grinder, were air-dried and packed for feeding. The procedures for the fish feed preparation and fish feed proximate composition determination are as described under sections 3.5 and 3.6 respectively.

The treatments I, I and III, corresponding to feeds I, II and III respectively, were each assigned to two cages using a completely randomized design. O. niloticus fingerlings (mean weight, 3.5g) were stocked at the rate of 0/m³ into the cages in the early morning.

The fish were fed with the pelleted feeds corresponding to their treatments, at rate of 10%, 5% and 3% of the fish biomass during the 1st, 2nd and 3rd plus 4th months of the experiment respectively. 10 of the fish stocked were sampled for growth at 30-day intervals. The fish were harvested after 120 days culture period (10 April - 7 August, 1988).

5.2.5 The Effect of different protein sources in supplementary feeds on Tilapia production in floating net-cages

Kigera III Reservoir located within the NIFFR Housing Estate, New Bussa (Figure 3.1) was the site

Table 5.1 Composition of three feed formulations fed to C. niloticus in floating net-cages for 120 days

Ingredient	Feed (%)		
	I	II	III
Blood meal	50	25	10
Corn bran/Layer's concentrates	49	74	89
Vitamin mix[a]	1	1	1

a A premix used in poultry feed manufacture ; contains oxytetracycline HCl, Vitamins A, D_3, E, K, B_2 and B_{12}, nicotinamide, calcium-d-pantothenate and antioxidant BHT.

for this experiment. A commercial feed (with soyabean meal as the major protein source) and three other feeds with different protein sources were tested. The composition of the feeds is shown in Table 5.2. The commercial feed was bought in pelleted form from the manufacturer (Nigerian Institute for Oceanography and Marine Research, Lagos). The other three feeds were prepared as described under section 3.5. The proximate composition determination of the four feeds was carried out as described under section 3.6.

The treatments I, II, III and IV correspond to feeds I, II, III and IV respectively. The treatments were assigned to net-cages (1m x 1m x 1.5m, with napa netting at the bottom to retain feed) using a completely randomized design and each treatment was replicated twice. O. niloticus fingerlings with mean weight of 20.0g were stocked at the rate of 50 fish/m^3 early morning. The fish were fed with pelleted feeds corresponding to their treatments at the rate of 5% body weight. 10% of the stock was sampled for growth and feed ration was adjusted monthly based on estimated biomass obtained from the sampling exercise. The fish were harvested after 120 days of culture period (7 July - 30 October, 1989).

Table 5.2 Composition of four feed formulations fed to O. niloticus in floating net-cages

Ingredient	Feed I	II	III	IV
	(%)			
Blood meal	-	25.0	-	-
Fish meal	-	-	25.0	-
Groundnut cake	-	-	-	25.0
[b]Layer's concentrate/ Corn bran (in ratio 1:3)	-	74.0	74.0	74.0
[c]Premix	-	1.0	1.0	1.0

a Feed I is a commercial feed composed of 34% SBM, 37% PKM, 26% WB, 2% CMC and 1% CO. Where

SBM - Soyabean meal
PKM - Palm kernel meal
WB - Wheat bran
CMC - Carbohydrate cellulose
CO - Chromic oxide

b The Layer's concentrate is a product of Bendel Feed Flour Mill Limited, Benin City, Nigeria. It is composed of fish meal, animal protein, groundnut cake, wheat bran, lime stone, minerals, vitamins, antioxidants and preservatives. Its nutrients analysis was given as: Crude protein, 26.2%; Crude fat, 4.0%; Crude fibre, 5.7%; Calcium, 9.4%; Phosphorus, 1.3%; Metabolizable energy, 1812 UE/kg.

c Premix used in poultry feed manufacture contains antioxidant, selenium, iodine, copper, iron, manganese, choline, chloride, methionine, lysine, riboflavin, vitamins A, D_3, E, B_3 and B_5.

5.3 RESULTS

5.3.1 Growth performance of tilapia fingerlings receiving different feedstuffs in floating net-hapas

5.3.1.1 Survival rates

Table 5.3 gives the results of some physico-chemical parameters obtained under this experiment. Table 5.4 shows the summary of results of Tilapia fry receiving different feedstuffs (Brewer's waste, Rice bran, Corn bran and no feeding representing treatments I, II, III and IV respectively). The highest average survival rate was recorded in treatment I, 94.0%; followed by treatment III, 90.0%; treatment II, 84.0% and least in treatment, IV (control), 78.0%.

5.3.1.2 Growth rates

Figure 5.1 shows the growth curves of tilapia fry receiving the different feedstuffs in floating net-hapas. By the end of the first week of the experiment, fish in treatments I and III took the lead and maintained it throughout the culture period. But by the second week treatment II shot up, leaving treatment IV (control) which lagged behind throughout till the end of the culture period.

5.3.1.3 Feed Conversion Ratio (FCR)

The mean feed conversion ratio for corn bran (treatment III) was 6.53, followed by that of brewer's waste, (treatment I) 7.14 and then rice bran (treatment II), 9.12 (Table 5.4).

Table 5.3 Some physico-chemical parameters of Kigera III Reservoir water during the culture period for experiment 5.2.1

	Range	Mean
pH	7.8 - 8.3	8.1
D.O (ppm)	3.0 - 5.7	3.8
Temperature (°C):		
Water	26.0 - 29.0	27.5
Air	28.0 - 36.0	31.5
Transparency (m)	0.45 - 0.75	0.54
Conductivity (µmhos/cm)	140 - 920	520

Table 5.4 Summary of results for Tilapia fry receiving different feedstuffs in floating net-hapas for 42 days.

Treatment	Replicate	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival Rate
I	1	0.37	1.24	0.0207	7.30	88.0
Brewer's	2	0.35	1.06	0.0169	8.19	96.0
Waste	3	0.29	1.27	0.0233	5.92	100.0
	Mean	0.34	1.19a	0.0203a	7.14a	94.0a
II	1	0.30	0.95	0.0155	8.10	86.0
Rice bran	2	0.42	1.06	0.0152	12.05	68.0
	3	0.48	1.29	0.0193	7.22	100.0
	Mean	0.40	1.10a	0.0167a	9.12a	84.0a
III	1	0.37	1.13	0.0181	7.64	92.0
Corn bran	2	0.33	1.27	0.0224	8.29	78.0
	3	0.29	2.40	0.0502	3.67	100.0
	Mean	0.33	1.60a	0.0302a	6.53a	90.0a
IV	1	0.31	1.40	0.0260	-	86.0
Control	2	0.30	0.92	0.0148	-	68.0
(No feeding)	3	0.24	0.83	0.0140	-	78.0
	Mean	0.28	1.05a	0.0183a	-	78.0a

Means in a column with the same superscript are not significantly different at 5% DMRT.

N.B. The 100% survival rates observed consistently in the third replicates of Treatments I, II and III are coincidental.

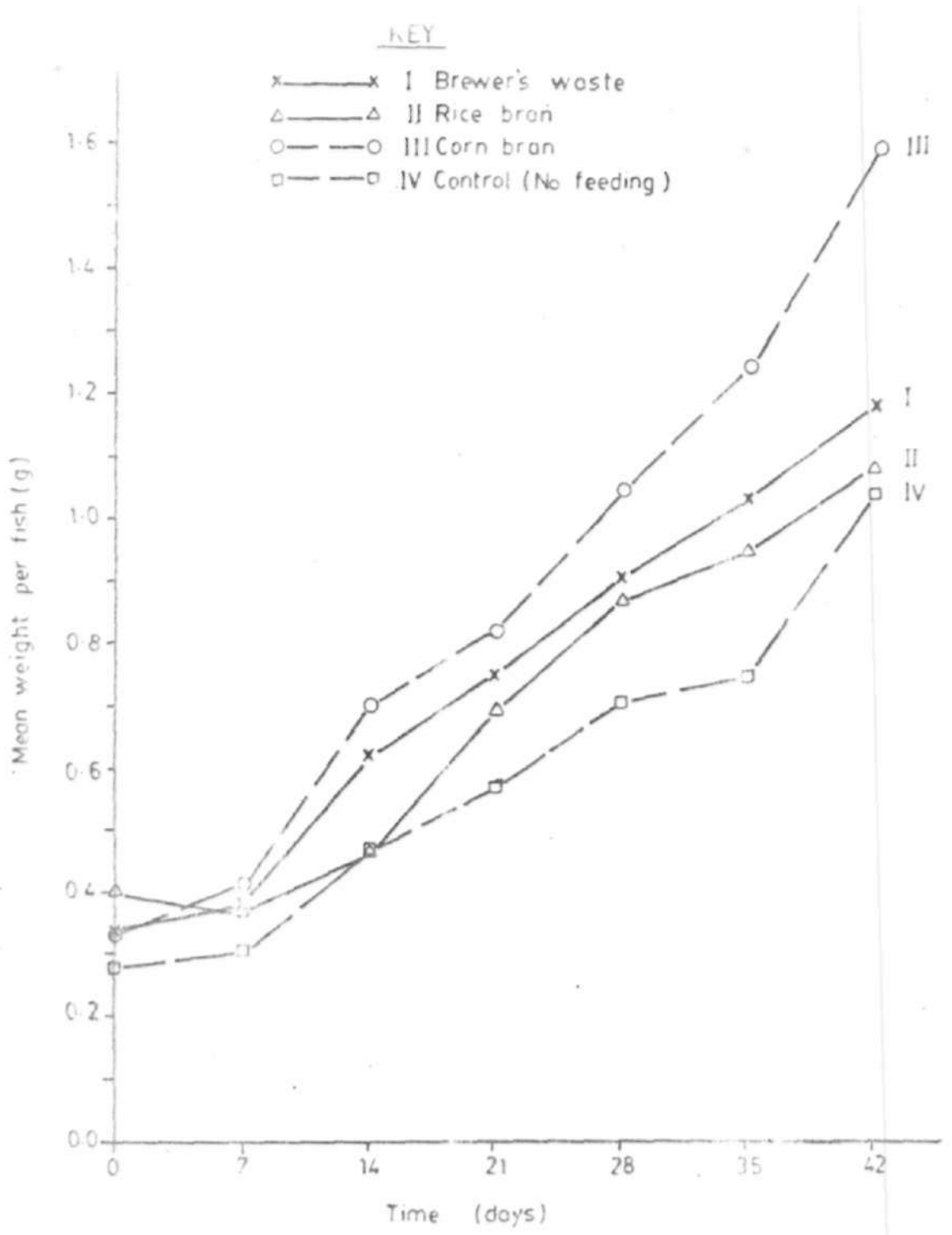


Fig. 5·1 Growth curves of Oreochromis niloticus fed different feedstuffs in floating hapas for 42 days.

5.3.2 Growth performance of tilapia fingerlings receiving different combinations of industrial wastes as supplementary feeds in floating net-hapas

5.3.2.1 Survival rates

Results of some physico-chemical analysis of the reservoir during this experiment are shown in Table 5.5. Table 5.6 shows the summary of results for Tilapia fry fed with different combinations of agricultural and industrial wastes in floating net-hapas for a period of 42 days. The range, 72.8 to 89.0% of the survival rates is similar to the range 78.0 to 94.0% obtained in the experiment where Tilapia fry (mean weight 0.34g) were fed single ingredients under section 5.3.1.

5.3.2.2 Growth Rates

The growth curves of the fish receiving different combinations of agricultural and industrial wastes in floating net-hapas are shown in Figure 5.2. Fry in treatment II fed with a mixture of corn bran and rice bran (in ratio 1:1) maintained the lead as from day 14 till the end of the experiment, followed by those in treatment III (corn bran + rice bran + brewer's waste, in ratio 1:1:1) while those in treatment II (corn bran only) lagged behind. Fish in treatment II had the best growth rate, 0.029g/day, then followed by treatment III, 0.026g/day and least in treatment I (control), 0.021g/day (Table 5.6).

Table 5.5 Range and mean of some physico-chemical parameters of Kigera III Reservoir during the period of experiment 5.2.2

Parameters	Range	Mean
Temperature (°C):		
Water	24.0 - 34.0	29.0
Air	24.0 - 39.5	31.8
pH	7.2 - 7.5	7.4
D.O (ppm)	4.5 - 6.0	5.3
Conductivity (µmhos/cm)	245 - 260	253

Table 5.6 Means of results of Tilapia fry receiving different combinations of agro-industrial by -products as feeds for a period of 42 days

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival rate (%)
I					
Corn bran only	0.043	0.93	0.021	5.67	87.0
	0.043	0.93	0.021	5.67	87.0
	0.043	0.93b	0.021a	5.67a	87.0a
II					
Corn bran + Rice bran (1:1)	0.032	1.21	0.028	4.57	62.5
	0.045	1.31	0.030	4.19	83.0
	0.039	1.26a	0.029b	4.38b	72.8a
III					
Corn bran + Rice bran + Brewer's waste (1:1:1)	0.046	1.18	0.027	3.99	91.0
	0.046	1.10	0.025	4.89	87.0
	0.046	1.14a	0.026c	4.44ab	89.0a

Means in a column with the same superscript are not siginficantly different at 5% DMRT.

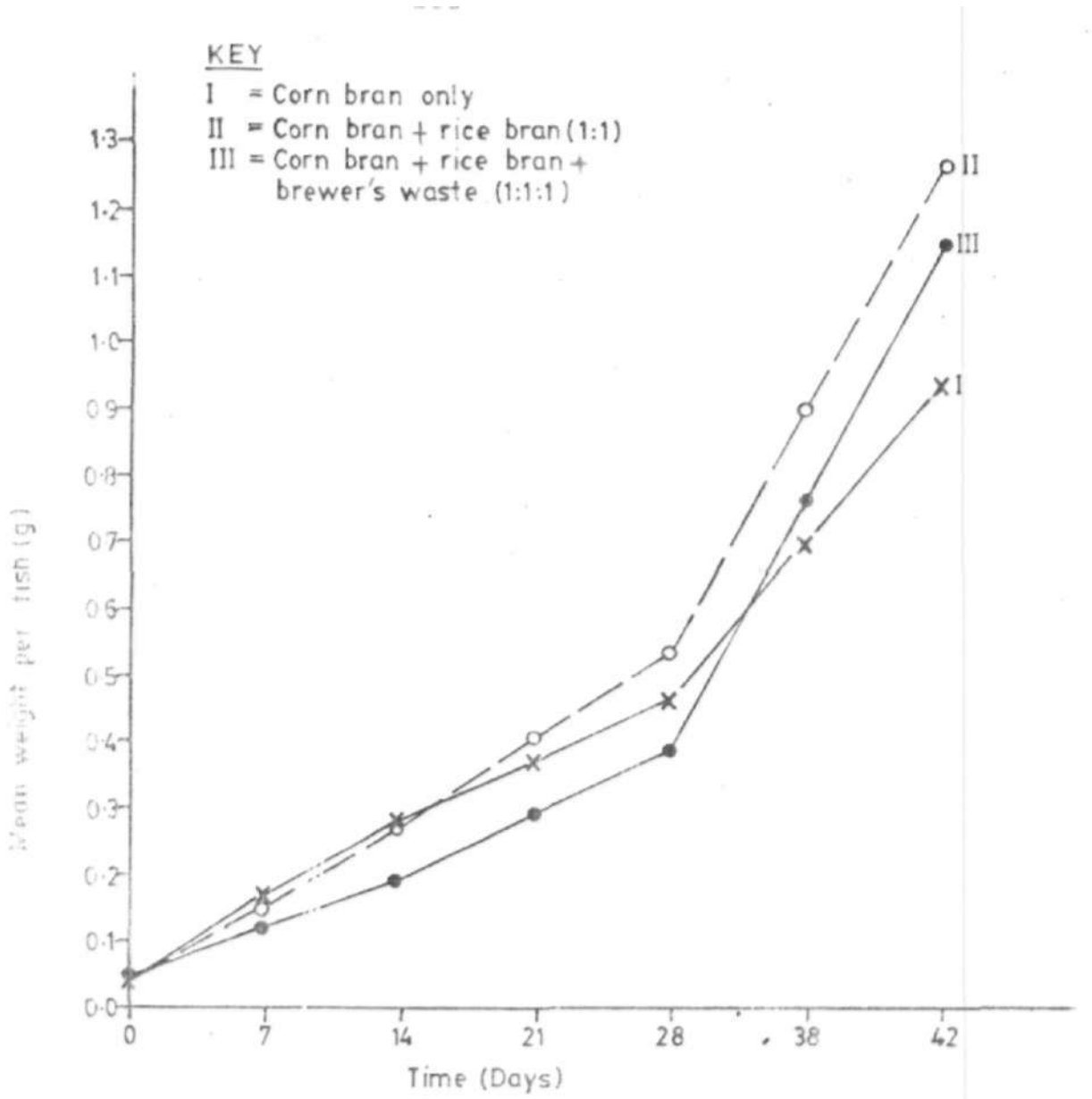


Fig. 5·2. Growth curves of Oreochromis niloticus fed different combinations of agroindustrial wastes in hapas for 42 days.

5.3.2.3 Feed Conversion Ratio

The best feed conversion ratio (FCR) 4.38, was recorded in treatment II (corn bran + rice bran in ratio 1:1), followed closely by treatment III (corn bran + rice bran + brewer's waste in ratio 1:1:1) 4.44 and worst, in treatment I (corn bran only), 5.67.

5.3.3 Growth Performance of Tilapia fingerlings fed with different agro-industrial wastes (added to constant amount of fish meal) in floating net-hapas

5.3.3.1 Survival rates

Table 5.7 shows the results of some physico-chemical parameters of the reservoir during this experiment. The survival rates (%) in this experiment ranged between 76.5 and 85.0 (Table 5.8) and compared well with the range 72.8 to 89.0 recorded in the experiment under section 5.3.2.

5.3.3.2 Growth Rates

Fish in treatment I had the highest growth rate, 0.1175g/day, followed closely by treatment II, 0.1171g/day, then treatment III, 0.0960g/day and least in treatment IV, 0.0865g/day (Table 5.8). Using the agro-industrial wastes as basis of describing the treatments the growth rates in decreasing order were corn bran > rice bran > brewer's waste > combination of corn bran/rice bran/brewer's waste (in ratio 1:1:1).

Table 5.7 Range and mean of some physico-chemical parameters of Kigera III Reservoir during the period of experiment 5.2.3 (Feb. - Mar.)

Parameters	Range	Mean
Temperature (°C):		
Water	28.0 - 38.0	33.0
Air	28.5 - 40.0	34.3
pH	7.1 - 7.5	7.3
D.O (ppm)	4.0 - 6.8	5.4
Transparency (m)	0.39 - 0.41	0.40
Conductivity (umhos/cm)	250 - 320	285

Table 5.8 Summary of results for Oreochromis niloticus receiving different agro-industrial bye-products added to constant amount of fish meal (FM) and premix for a period of 42 days in floating net-hapas

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival Rate (%)
I					
Corn bran + FM + Premix	0.06	4.80	0.1129	1.06	73.0
	0.08	5.21	0.1221	1.19	83.0
	0.07	5.01ab	0.1175a	1.13a	78.0a
II					
Rice bran + FM + Premix	0.13	4.59	0.1062	1.11	66.0
	0.06	5.43	0.1279	1.17	87.0
	0.10	5.01a	0.1171ab	1.29b	76.5a
III	0.09	4.11	0.0957	1.30	86.0
Brewer's waste + FM + Premix	0.05	4.09	0.0962	1.16	67.0
	0.07	4.10abc	0.0960abc	1.23c	76.5a
IV					
Corn bran + Rice bran + Brewer's waste (1:1:1) + FM + Premix	0.03	3.93	0.0928	1.24	75.0
	0.06	3.43	0.0802	1.10	95.0
	0.05	3.68c	0.0865c	1.17d	85.0a

Means in a column with the same superscript are not significantly different at 5% DMRT

FM = Fish meal.

5.3.3.3 Feed Conversion Ratio (FCR)

The best feed conversion ratio, 1.13 was recorded under treatment I, followed by treatments IV, III and II which were 1.17, 1.23 and 1.29 respectively.

5.3.4 Growth performance of Tilapia (Oreochromis niloticus) fed different levels of blood meal in pelleted feeds in floating cages

5.3.4.1 Survival rates

Table 5.9 gives the results of some physico-chemical parameters of the reservoir during this experiment. Generally, the survival rates under this experiment were very high. Treatment III (10% blood meal in pelleted feed) had the best survival rate, 100%; closely followed by treatment I (50% blood meal in pelleted feed) 99.5% and treatment II (25% blood meal in pelleted feed), 99.0% (Table 5.10).

5.3.4.2 Growth rates

The results of the proximate analysis of the blood meal feeds are shown in Table 5.11. The growth curves for the fish (O. niloticus) fed on these diets are shown in Figure 5.3. Fish in treatment III (31.34% crude protein containing 10% blood meal in pelleted feed) consistently grew

Table 5.9 Range and mean of some physico-chemical parameters of Kigera III Reservoir during the period of the experiment 5.2.4

Parameter	Range	Mean
Temperature (°C):		
Water	25.8 - 31.6	29.4
Air	26.5 - 32.5	30.5
pH	6.9 - 7.6	7.1
D.O (ppm)	2.8 - 4.8	3.6
Conductivity (µmhos/cm)	63 - 160	124

Table 5.10 Summary of results for Oreochromis niloticus receiving different levels of blood meal in pelleted feeds in floatin cages for 120 days.

Treatment	Average Wt. (g) Initial	Final	Average Wt. gain (g)	Relative Wt. gain (%)	Survival Rate (%)	FCR	Total Fish Prodn (kg/m³)
I	3.1	15.0	11.9	383.9	99.0	2.84	1.485
50% Blood meal	3.7	25.0	21.3	575.7	100.0	1.49	2.500
	3.4	20.0a	16.6a	479.8a	99.5a	2.17a	1.993a
II	3.2	25.0	21.8	681.3	99.0	1.81	2.475
25% Blood meal	3.3	45.0	41.7	1263.6	99.0	0.91	4.455
	3.3	35.0a	31.8a	972.5a	99.0a	1.36a	3.465a
III	3.5	44.4	40.9	1168.6	100.0	1.19	4.440
10% Blood neal	4.0	33.8	29.8	745.0	100.0	2.14	3.380
	3.8	39.1a	35.4a	956.8a	100,0a	1.67a	3.910a

* Relative Wt. gain (%) = $\frac{\text{(Final Average Wt. - Initial Average Wt.)}}{\text{Initial Average Wt.}} \times 100$

Mean in a column with the same superscript are not significantly different at 5% DMRT.

Table 5.11 Proximate analysis of the three blood meal feeds (%)

Feed	Crude Protein	Crude Fat	Crude Fibre	Ash	NFE	Ca	P
I	49.07	0.61	3.60	5.31	41.41	1.14	0.07
II	46.87	0.95	3.71	6.81	42.36	1.36	0.11
III	31.34	1.26	4.14	5.90	57.36	1.30	0.10

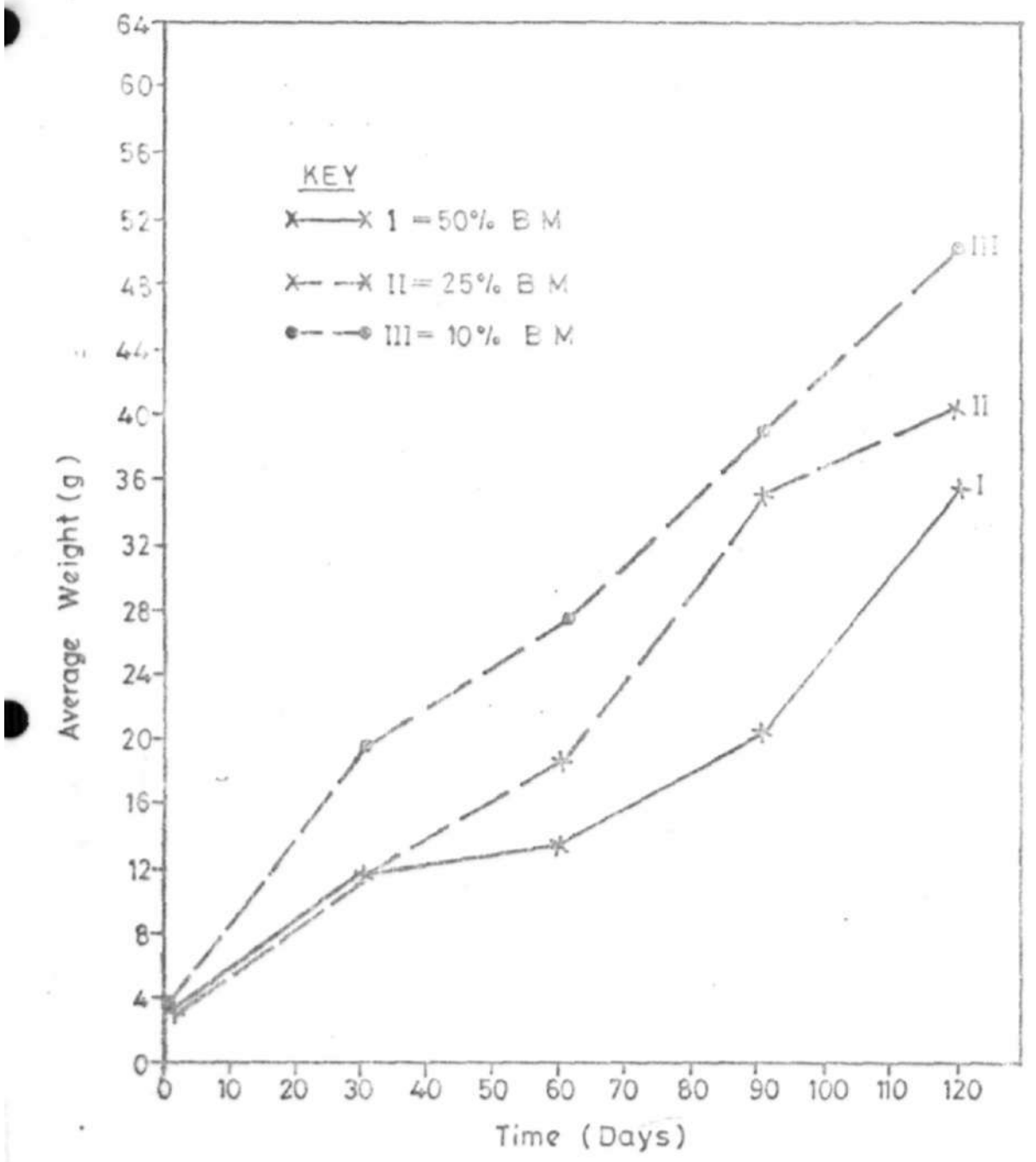


Fig. 5·3 Growth curves of Sarotherodon (Tilapia) niloticus receiving feeding treatments for a period of 120 days.
(B·M=Blood meal)

fastest throughout the culture period; treatment II (46.87% crude protein, containing 25% blood meal) overtook treatment I (49.07% crude protein, containing 50% blood meal) till the end of the culture period.

5.3.4.3 Feed Conversion Ratio (FCR)

The best FCR was obtained with treatment II in which 25% blood meal in pelleted feed was fed to Tilapia fingerlings, followed closely by treatment III (10% blood meal) and worst in treatment I (50% blood meal) (Table 5.10). The trend in the FCRs was similar to that of the relative weight gain: treatment II > treatment III > treatment I (Table 5.10). The FCRs were therefore very much truly representative of the efficiency of the different feeds.

5.3.4.4 Total Fish Production

At the end of the 120-day culture period, the highest mean total fish production, 3.910kg/m³ was obtained in treatment III (10% blood meal), followed closely by treatment II (25% blood meal), 3.465kg/m³ and least in treatment I (50% blood meal), 1.993kg/m³ (Table 5.10).

5.3.5 Growth Performance of Tilapia (Oreochromis niloticus) fed with different protein sources in pelleted feeds in floating net-cages

5.3.5.1 Survival rates

The results of some of the physico-chemical parameters of the reservoir during this experiment are given in Table 5.12. The survival rates are shown in Table 5.13.

Table 5.12 Range and mean of some physico-chemical parameters in Kigera III Reservoir during the feeding experiment 5.2.5

Parameters	Range	Mean
Temperature (°C):		
Water	26.0 - 29.0	27.5
Air	29.0 - 31.0	30.0
D.O (ppm)	2.40 - 4.50	4.45
pH	7.0 - 7.4	7.2
Conductivity (µmhos/cm)	200 - 350	275

Table 5.13 Summary of results of Oreochromis niloticus receiving different protein sources in pelleted feeds in floating net-cages for 120 days.

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival Rate (%)	Total Fish Prodn (kg/m³)
I	21.0	87.0	0.55	1.51	70.0	3.045
Commercial feed	21.0	81.0	0.50	1.42	80.0	3.240
	21.0	84.0a	0.53a	1.47a	75.0a	3.143a
II	21.0	93.0	0.60	1.33	84.0	2.906
Blood meal in	21.0	103.8	0.69	1.31	62.0	3.218
feed	21.0	98.4b	0.65b	1.32b	73.0a	3.562a
III	21.0	64.2	0.36	1.86	72.0	2.311
Fish meal in	20.0	65.6	0.38	1.86	54.0	1.771
feed	20.5	64.9c	0.37c	1.86c	63.0a	2.041a
IV	19.0	113.8	0.79	1.14	76.0	4.324
Groundnut cake	19.0	113.8	0.79	1.09	60.0	3.414
in feed	19.0	113.8d	0.79d	1.12d	68.0a	3.869b

Means in a column with the same superscript are not significantly different at 5% DMRT.

The highest mean survival rate, 75.0% was recorded in treatment I, followed closely by 73.0% in treatment II; 68.0% in treatment IV and least 63.0% in treatment III.

5.3.5.2 Growth rates

The results of the proximate analysis of the feeds used under this experiment are shown in Table 5.14. Figure 5.4 shows the growth curves of the fish receiving these pelleted feeds in floating net-cages. The mean daily weight gain per fish were 0.79, 0.65, 0.53 and 0.37 g/day in treatments IV, II, I and III respectively (Table 5.13).

5.3.5.3 Feed Conversion Ratio (FCR)

The best feed conversion ratio, 1.12 was obtained in treatment IV, followed by 1.32 in treatment II; then treatment I, 1.47 and least in treatment III, 1.86 (Table 5.13). A critical analysis of the values of mean final weight (per fish), daily weight gain and feed conversion ratio showed that the performance of the feeds in descending order was treatment IV (groundnut) > treatment II (blood meal) > treatment I (soyabean meal) > treatment III (fish meal).

5.3.5.4 Total Fish Production

The trend in the values of the total fish

Table 5.14 Proximate analysis of the four feeds used.

Feed	Crude Protein	P	K	Ca	Mg	Mn	Na	Fe	Ash	Moisture
I Commercial feed (Soyabean meal protein source)	24.52	0.0578	0.080	0.044	0.0316	0	0.0120	0.018	8.0	5.30
II Blood meal in feed	40.28	0.0609	0.280	0.172	0.0134	0	0.0044	0.045	9.9	5.10
III Fish meal in feed	33.27	0.0864	0.052	0.220	0.0160	0	0.0280	0.019	11.8	6.65
IV Groundnut cake in feed	28.02	0.0485	0.040	0.132	0.0172	0	0.0044	0.015	8.9	8.30

NB All figures expressed in percentages except for Mn in ppm.

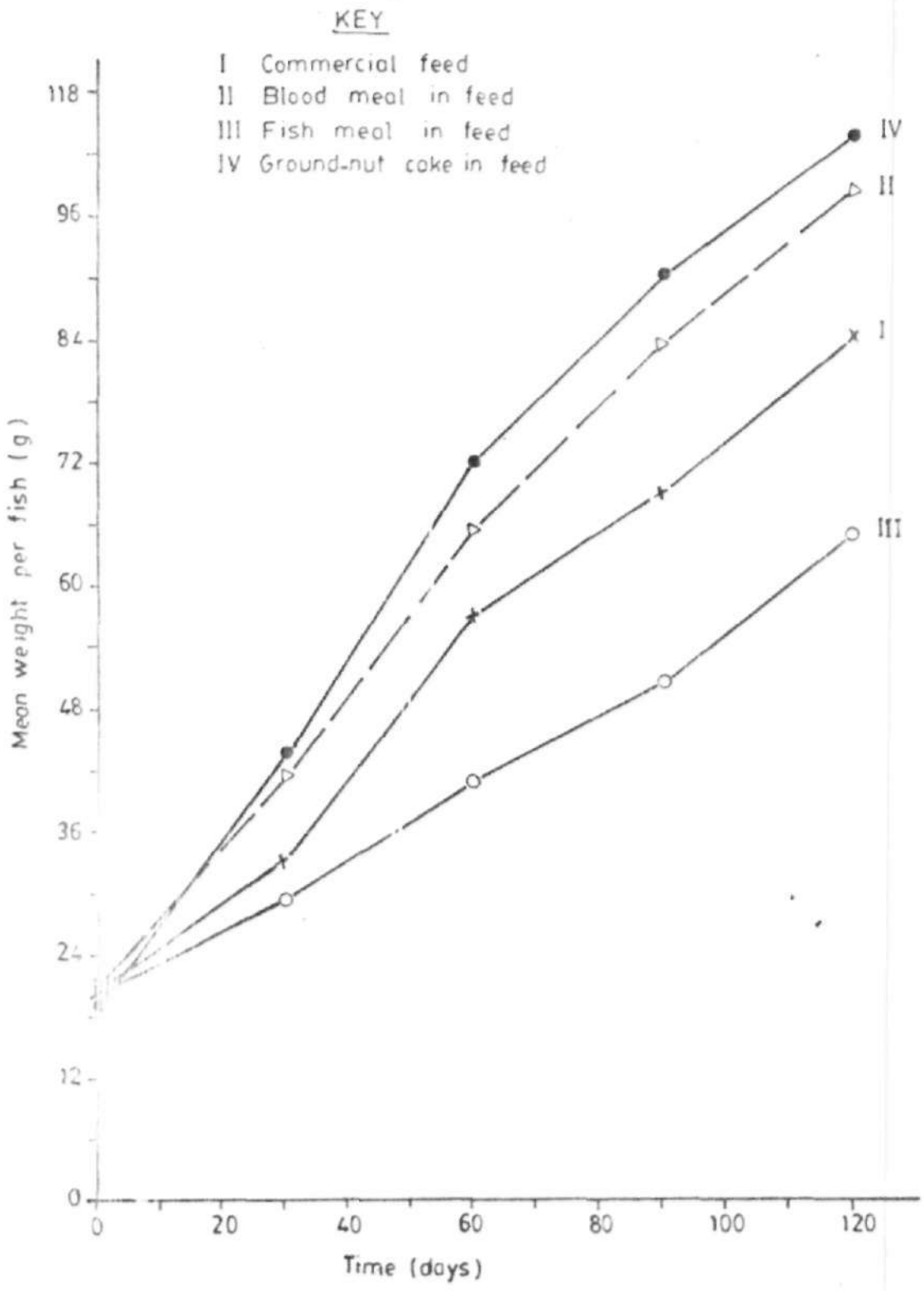


Fig. 5.4 Growth curves of Oreochromis niloticus fed different protein sources in cages for 120 days.

production is very similar to those in mean final weight, daily weight gain and feed conversion ratio that is - treatment IV > treatment II > treatment I > treatment III (Table 5.13). The highest total fish production of 3.869 kg/m³ was obtained in treatment IV (groundnut cake in feed) followed by treatment II, 3.562 kg/m³ (blood meal in feed), then treatment I 3.143 kg/m³ (commercial feed) and least in treatment III, 2.041 kg/m³ (fish meal in feed) (Table 5.13).

5.4 DISCUSSION

5.4.1 Growth Performance of Tilapia fingerlings receiving different feedstuffs in floating net-hapas

5.4.1.1 Survival Rates

The mortality recorded during the experiment was mainly due to sampling stress while the generally high survival rates were partly attributed to the proper management of the stock (fry) and the physico-chemical parameters (Table 5.3) which were within tolerable range as suggested by Balarin (1979) for tilapia fingerlings production. The pH and water transparency at the site were also observed to be within the desirable range as reported by Swingle (1969) and Boyd (1979), and Huet (1979). However, there were no significant differences ($P > 0.05$) between the mean survival rates of the treatments.

5.4.1.2 Growth Rates

The observations of the sharp and steady increases in the growth rates of the fish under the different treatments could be attributed to the adaptation of the experimental fish to the environment and the different feedstuffs dispensed to them.

Generally, the growth performances of the fish on these feedstuffs could be related to the crude protein, fat and carbohydrate contents of the feedstuffs used. The best growth rate (0.0302g per day) observed in fish fed with corn bran (64.4% carbohydrate) corroborated the observation of Coche (1977) who reported that since O. niloticus is an omnivore with a vegetarian tendency in its natural environment, its ideal diet a priori should contain a relatively high percentage of carbohydrate as an energy source. Coche (1977) observed that O. niloticus could accept very high levels of carbohydrate diet. Rice bran which was analyzed to contain 8.7% crude protein and 3.8% fat had the second highest carbohydrate content (56.9%); brewer's waste (crude protein 18.3%; fat Nil and carbohydrate 45.9%). Even though, the carbohydrate content of brewer's waste was less than that of rice bran, the higher growth rate observed in fish fed brewer's waste (treatment I) could be as a result of the higher protein content (18.3%).

In addition, the stability of the three feedstuffs in water could have contributed to their effective utilization for growth by the experimental fish. Corn bran was observed to float almost indefinitely on the water surface inside the hapas, thus allowing the fry to feed on it and utilize it for growth. However, the mean daily weight gain in treatment III (corn bran) was not significantly different ($P > 0.05$) compared to those of the other three treatments (Table 5.4).

5.4.1.3 Feed Conversion Ratio (FCR)

The trend of the feed conversion ratios was similar to that of the daily growth rates of the fish under the different treatments. The FCR range, 6.53 to 9.12 for the three feedstuffs in this experiment was similar to the FCR values of 5.0 and 8.0 obtained for cereals and rice hull respectively fed to tilapia (FAO, 1976). The mean FCR for rice bran (treatment II) was not significantly different ($P > 0.05$) compared to those of brewer's waste (treatment I) and corn bran (treatment III). The digestibility, stability and nutrient contents of the different feedstuffs could be attributed to the varying FCRs. Corn bran was observed to give the best FCR (6.53), highest mean final weight per fish (1.60g), and highest mean daily weight gain (0.0302g per day). Surprisingly, rice bran reported as the most

important feedstuffs of indigenous origin in Asia especially in the Philippines (FAO, 1983) recorded the worst FCR (9.12) and the least growth rate (0.0167g per day). Perhaps the rice milling method and the rice varieties from which the rice bran (used in this experiment) was obtained from the rice mill at New Bussa, Nigeria is different from that of the Philippines and hence the poor fish growth performance. This observation corroborates that of Wanigama et al. (1985) who reported poor digestibility of diets containing varying levels of rice bran (in cage culture of O. niloticus) and attributed the poor digestibility to the quality of the rice bran. In spite of this, the best growth performances observed in fish fed corn bran was as a result of corn bran containing the highest carbohydrate contents.

5.4.2 Growth Performances of Tilapia fingerlings receiving different combination of industrial and agricultural wastes as supplementary feeds in floating net-hapas

5.4.2.1 Survival Rates

The overall mean survival rate (82.9%) in this experiment was slightly less than that reported under section 5.3.1 (86.9%) (Table 5.4). This could be attributed to the smaller size of fry (0.039 - 0.046g) stocked under this experiment compared to size of fry (0.28 to 0.40g) reported under section 5.3.1. In spite of this difference, generally the

survival rates were high in the experiment but the means were not significantly different ($P > 0.05$). The high survival rates were partly attributable to the tolerable range of the physico-chemical parameters (Table 5.5) observed during the experimental period (Balarin, 1979; Lloyd, 1979). But, the hapa used for one of the replicates in treatment II suffered loss of some fry through the accidental lowering into water of the top cover of the hapa coupled with the intrusion of one Hemichromis niloticus (a carnivorous Tilapia) into the hapa. This was later detected and removed promptly to avert further predation of the fry stocked.

5.4.2.2 Growth Rates

The growth performances of the fish on these combinations of feedstuffs could be attributed to the nutrients contents of the various feedstuffs used. The highest growth rate recorded by fish in treatment II could be related to the nutrient contents (%) of the feedstuffs: crude protein, carbohydrate and fat were 12.2, 64.4 and 8.6 respectively for corn bran while for rice bran, 8.7, 56.9 and 8.7 respectively (Ezenwa, 1978; Eyo, 1990). The nutrient contents (%) of brewer's wastes were 18.3, crude protein; 45.9 carbohydrate and 0.0, fat (Ezenwa, 1978). Generally, the fish under treatments II and III which involved combinations of feed ingredients (i.e. more

than one feed ingredient) recorded higher growth rates than that under a single feed ingredient, treatment I (corn bran only). Considering the mean final weight (g), there was no significant difference ($P > 0.05$) between treatments II and III (involving more than one feed ingredient) whereas there was significant difference between them (treatments II and III) and treatment I (corn bran only). This observation agrees with the report of IDRC/SEAFDEC (1979) where it was noted that the use of simple diets, either single ingredient or formulated out of locally available sources, was practised in many developing countries. The range of growth rates (g/day), 0.021 to 0.029 in this experiment was comparable to the range, (g/day) 0.0167 to 0.0302 obtained using single feed ingredient in experment under section 5.3.1, even though the initial sizes of fish used in the latter experiment were about 10 times (in weight) heavier than those under section 5.3.2. There were significant differences in the mean growth rates (g/day) between all the three treatments ($P < 0.05$).

5.4.2.3 Feed Conversion Ratio (FCR)

The range of FCR (4.38 to 5.67) recorded in this experiment was better than the range 6.53 to 9.12 recorded in experiment under section 5.3.1 where single ingredient feedstuffs were fed to Tilapia fry.

The fact that the FCR, 5.67 for corn bran only (treatment I) in this experiment was very close to the FCR, 6.53 also for corn bran only under section 5.3.1 confirmed that the FCRs 4.38 and 4.44 recorded in treatments II and III respectively in this experiment proved the superiority of the combined ingredients feeds used in treatments II and III. However, only the mean of FCR of treatments I and II were significantly different ($P < 0.05$). The FCR range 4.38 to 5.67 obtained in this experiment was better than the range 5.0 to 8.0 reported by FAO (1976) for cereals and rice hulls respectively fed to Tilapia.

Various factors such as digestibility, water stability and nutrients composition of the feedstuffs could be responsible for the differences in the feed conversion observed in this experiment.

5.4.3 Growth Performance of Tilapia fingerlings fed with different agro-industrial wastes (added to constant amount of fish meal) in floating net-hapas

5.4.3.1 Survival Rates

The physico-chemical parameters (Table 5.7) observed during the experiment were within tolerable limits for Tilapia growth (Balarin, 1979). The mean air (ambient) and water temperatures were slightly higher (34.3°C and 33.0°C respectively, Table 5.7) because the culture period coincided with the hot, dry season around Lake Kainji area. However, the mean

survival rates of all the treatments were not significantly different ($P > 0.05$).

5.4.3.2 Growth Rates

The trend in the growth performances of fish in this experiment was almost similar to the effect of the single ingredient feedstuffs (i.e. corn bran, rice bran and brewer's wastes) when they were fed singly in the feedstuffs-screening experiment discussed under section 5.3.1. Tilapia growth rates (g/day) were: corn bran, 0.0302 > brewer's wastes, 0.0203 > rice bran, 0.0167. Clearly, corn bran with the highest carbohydrate content, (64.4%) proved to be consistently superior to the other feedstuffs (i.e. rice bran and brewer's waste with carbohydrate contents of 56.0% and 45.9% respectively) (FAO, 1983). Furthermore the addition of fish meal (ground clupeids, mixture of Pellonula afzeliusi and Sierrathrissa leonensis, 70.0 - 75% crude protein, Eyo, 1990) to the various agro-industrial wastes greatly enhanced their performances towards increased fish growth. Lovell (1981) reported that fish meal was high in calcium, potassium and phosphorus and all the other minerals required by fish and therefore recommended it (fish meal) as a good source of all these nutrients. Akiyama (1988) concluded that the exceptionally well balanced amino acids distribution of fish meal has made it (fish meal) a traditional component of fish feeds. Comparing

the growth rates (g/day) of fish in the experiments under sections 5.3.1, 5.3.2 and 5.3.3, fish under experiment of section 5.3.3 had the highest growth rates (range 0.0865g/day to 0.1175/day) and they attained a size range of 3.68g to 5.01g (Table 5.8) within the same culture period of 42 days as in experiments under sections 5.3.1 and 5.3.2. There were significant differences ($P < 0.05$) between the mean growth rates of fish under all the treatments (Table 5.8).

5.4.3.3 Feed Conversion Ratio (FCR)

The range of these FCR values, 1.13 to 1.29 was best, compared with the range 4.38 to 5.67 obtained using different combinations of the feedstuffs (corn bran, rice bran and brewer's wastes) (Table 5.6) and the range 6.53 to 9.12 obtained in the experiment where the feedstuffs (corn bran, brewer's waste and rice bran) were fed singly to Tilapia fry (Table 5.4).

The low values of FCR under this experiment 5.3.3 further confirmed the efficiency and acceptability of fish meal as a good source of the nutrients required by fish for growth (Lovell, 1981; Akiyama, 1988). Even though the use of fish meal in fish diets appeared limited only by high cost and availability (FAO, 1983). However, there were significant differences ($P < 0.05$) between the means of FCR in all the treatments (Table 5.8).

5.4.4 Growth performances of Tilapia (Oreochromis niloticus) fed different levels of blood meal in pelleted feeds in floating cages

5.4.4.1 Survival rates

These high survival rates were partly attributable to proper management of the stock and

the favourable (within tolerable limits) physico-chemical parameters of the water in the culture site during the culture period (Table 5.9) (Swingle, 1969; Balarin, 1979; Boyd, 1979). There were no significant differences ($P > 0.05$) in the means of survival rates in all the treatments.

5.4.4.2 Growth Rates

The growth rates of the fish under the different treatments in this experiment were inversely related to the percentage of blood meal in the pelleted feeds. This observation is contrary to those made by Otesi and Ufodike (1986) on snake head (Channa obscura) which had an increase in growth rate as the crude protein (12% to 21%) of the diets increased and Jauncey (1981) on Sarotherodon mossambicus in which growth was proportional to the amount of protein in the diet. The implications to fish growth of the different levels of blood meal in the pelleted feeds are appropriately discussed under feed conversion ratio (section (5.4.4.3). However, there were no significant differences ($P > 0.05$) in the means of the relative weight gain (%) between all the three treatments (Table 5.10).

5.4.4.3 Feed Conversion Ratio (FCR)

The FCR values indicated that all three feeds were accepted by the fish and were utilized for growth.

It was very striking that the feed containing the highest amount of blood meal (50%) gave the poorest performance in terms of growth (479.8%) (Table 5.10). This observation corroborated the fact that protein fed in excess of an animal's needs is deaminated and does not contribute to the animal's growth (Cullison, 1979). This is further confirmed by Harper (1967) and Russell-Hunter (1970) that protein at higher levels is in excess of the animal's ability to utilize it anabolically and thus growth decreases presumably as a result of the energetic cost of protein catabolism. The best performance in terms of FCR (1.67), relative weight gain (950.8%) and daily weight gain (0.39g/day) was achieved with the feed containing 10% blood meal (31.34% protein) (Tables 5.10 and 5.11). This confirms the observation that 27% protein feed is suitable for intensive culture of tilapia (ADCP, 1983). Even though, blood meal is extremely high in protein (about 80% protein), it is low in isoleucine, but high in lysine (FAO, 1983); the combination of this rich protein source with corn bran (low in lysine but high in isoleucine) helped to enrich the feedstuffs compounded (Harris, 1980). Recce and Wesley (1975) observed that fresh bovine blood in combination with rumen contents successfully substituted for fish meal in channel catfish diets. This animal protein source (blood meal) is often obtained at little or no cost

from local abattoirs where it is often discarded. Fowler and Banks (1976) noted that blood meal was superior to meat meal in test-diets for salmon. Blood meal, therefore, has a great potential as an inexpensive, effective and readily available protein supplement in aquaculture diets.

5.4.4.4 Total Fish Production

Campbell (1985) observed that fish production was directly related to the quality and amount of feed given to the fish under culture. Cho et al. (1985) noted that a well balanced diet, however, not only resulted in higher fish production but also provided the nutrients necessary to hasten recovery from diseases or aid the fish in overcoming the effects of environmental stress. The best growth performance by the feed containing 10% blood meal was evident by its recording the highest mean final weight (39.1g), highest mean weight gain (35.4g) and the highest mean total fish production (3.910 kg/m³). This value is comparable to the total fish production of 3.4g/m³ in 90 days obtained by

Pantastico and Baldia (1979) feeding 20% fish meal in feed at 10% biomass to Sarotherodon mossambicus stocked at 50/m³ of cage. Philippart et al. (1979) feeding soya pellets (30% protein) at 4.8% biomass

to monosex male Tilapia guineensis stocked at 86/m³ in cages also obtained a similar average monthly fish production of 0.96 kg/m³.

The potentials of blood meal in fish diets for increased fish production have been discussed under section 5.4.4.3.

5.4.5 Growth Performances of Tilapia (Oreochromis niloticus) fed with different protein sources in pelleted feeds in floating net cages

5.4.5.1 Survival rates

The range 63.0% to 75.0% of the survival rates in this experiment was lower than the range 99.0% to 100.0% obtained in the blood meal in feed experiment under section 5.3.4 (Table 5.10). The generally low survival rates was due mainly to sampling stress because mortality was often recorded shortly after some of the sampling exercises. The means of the physico-chemical parameters (Table 5.12) observed in the culture site water were within tolerable range for tilapia culture (Balarin, 1979; Boyd, 1979). There were no significant differences between the mean survival rates of the treatments ($P > 0.05$).

5.4.5.2 Growth Rates

The feed (28.02% CP, Table 5.14) containing groundnut cake as major protein source used in treatment IV gave the highest daily weight gain (0.79g/d). This observation corroborates the report by ADCP (1983) that 27% protein feed was suitable

for intensive culture of tilapia. Even though, it was not possible to analyze every nutrient composition parameters of the experimental feeds in order to obtain the nitrogen free extract (NFE) value, the groundnut cake must have contributed the highest lipid content to the feed used under treatment IV compared with other feeds in the other treatments. The protein-energy ratio of the feed (used in treatment IV) must have been quite ideal and therefore recorded the highest average daily growth rate. This is similar to the observations of Bruton and Allanson (1974), Bruton and Boltt (1975) and Bowen (1979) in the studies of the feeding of Sarotherodon mossambicus. The growth rate, 0.79 kg/day in treatment IV (28.02% protein) compared very well with the growth rate, 0.73g/day obtained by Ishak and Tanen (1985) feeding 29.0% crude protein (CP) feed to O. niloticus in cages for 120 days in Egypt. The efficiency of groundnut cake as a protein source in fish feed was further confirmed by FAO (1983) which reported that in India it was demonstrated that diets containing 50% groundnut cake as principal protein source could be used as complete feeds for carp.

The growth rate in fish fed with blood meal protein source (feed, 40.28% CP in treatment II, Table 5.14) was the second best, despite the fact that this feed had the highest crude protein content. This observation further confirmed the results obtained

under the experiment in section 5.2.4 where pelleted feeds containing different levels of blood meal were fed to Oreochromis niloticus. It had earlier been discussed that Cullison (1979) noted that protein fed in excess of an animal's needs is deaminated and does not contribute to the animal's growth.

The feed (33.27% CP) in treatment III with fish meal as the major protein source surprisingly recorded the least growth rate of 0.3691g/day (Table 5.13), even though, Anonymous (1979) reported that in the Philippines a ration consisting of 77% rice bran and 23% fish meal was found adequate for tilapia production. A better and perhaps more accurate picture of the performance of the fish meal feed (in treatment III) was presented by Guerrero (1980) in the studies on the feeding of tilapia (100/m^3, O. niloticus) different levels of fish meal (25%, 30% and 35%) in floating cages in the Philippines. Guerrero (1980) obtained the highest growth rate of 0.32g/day with the feed containing 25% fish meal and least growth of 0.23g/day with 35% fish meal feed. In this experiment on different protein sources in feeds, the feed containing 25% fish meal (treatment III)

recorded a growth rate of 0.37g/day (Table 5.13) which was comparable to 0.32g/day obtained by Guerrero (1980) using a combination of 25% fish meal and 75% rice bran.

Though the commercial feed used under treatment I was supposed to contain 30% CP minimum (as specified on the production tag by the manufacturer) but proximate analysis showed that it contained 24.52% CP, (Table 5.14). It was therefore, not surprising that this feed (commercial feed) recorded a growth rate of 0.53g/day (Table 5.13) which was less than those of blood meal and groundnut cake separately in feeds under treatments II and IV respectively (Table 5.13). However, the growth rate 0.53g/day obtained using the commercial feed (soyabean as main protein source, treatment I, Table 5.13 and Figure 5.4) was higher than the growth rate, 0.40g/day obtained by Philippart et al. (1979) feeding soya pellets (30% protein) to Tilapia guineensis stocked at 86/m² in cages.

The mean growth rates of fish in all the treatments were significantly different ($P < 0.05$).

5.4.5.3 Feed Conversion Ratio (FCR)

The FCR value of 1.47 obtained in treatment I (commercial feed) in this experiment was better than the FCR value, 2.2 reported by Philippart et al.(1979) feeding commercial pellets (46% protein) to O. niloticus at 100/m³ in cages. In treatment II (25% blood meal as protein source) the FCR value of 1.32 recorded was comparable to the FCR value of 1.36 reported under

experiment in sections 5.2.4 and 5.3.4 (Table 5.10) also involving 25% blood meal in pelleted feed. The FCR, 1.32 for treatment II under section 5.2.5 was better than FCR, 1.36 for treatment II under section 5.2.4 and could be attributed to better utilization of the pelleted feed (under section 5.2.5) because feed loss/wastage was reduced to the barest minimum by the hapa-netting sewn to the under side of the bottom wall of the net-cages used in this experiment (section 5.2.5). The pelleted feeds dispensed settled on the fine-meshed hapa netting from which the fish fed on the sinking feed. This observation was corroborated by Guerrero (1980) who reported that the relatively poor conversion ratios of the diets (made from different levels of fish meal) by O. niloticus in cages could be partly explained by feed wastage. It was therefore not surpising that 25% fish meal in pelleted feed in treatment III gave a better feed conversion ratio of 1.86 than the FCR value of 3.1 obtained by Guerrero (1980) feeding 25% fish meal and 75% rice bran as a mash to O. niloticus in cages.

The feed conversion ratio, 1.12 obtained using 25% groundnut cake in feed (28.02% crude protein) in this experiment was better than the FCR value of 2.23 reported by Campbell (1985) feeding 28.0% protein feed (made up of 11% groundnut cake, 20% cotton seed cake and 9% fish meal (tuna waste) as major protein

sources) under large scale cage farming of Sarotherodon niloticus in the Ivory Coast. The FCR, 1.12 (in treatment IV) was also superior to the FCR value, 2.90 obtained by Ishak and Hassanen (1985) in the 120-day cage rearing of O. niloticus fed with 29.0% protein feed made up of 8% fish meal, 5% meat meal and 26% cotton seed meal as major protein sources.

Generally, the feed conversion ratios (range 1.12 to 1.86) (Table 5.13) obtained under this experiment were better than the FCRs (range 1.36 to 2.17) reported under the experiment in sections 5.2.4 and 5.3.4 (Table 5.10) using different levels of blood meal in pelleted feeds.

All the means of the FCR of all the treatments in this experiment were significantly different ($P < 0.05$).

5.4.5.4 Total Fish Production

Campbell (1985) reporting on the large scale commercial cage farming of Sarotherodon niloticus concluded that fish production was directly related to the amount and quality of feed given. This was corroborated by the direct relationship observed between the FCR values and total fish production since FCR can serve to some extent, as an indicator of the efficiency or nutritional value of the feeds (Hepher and Pruginin, 1982). Treatment IV which had

the best FCR (1.12) recorded the highest total fish production (3.869 kg/m³) while treatment III with the least FCR (1.86) had the least total fish production (2.041 kg/m³) (Table 5.9). The range (2.041 to 3.869 kg/m³) of mean fish production obtained in this experiment lasting only 120 days (but ranged between 9.854 and 15.630 kg/m³ in 365 days) was better than the range, 0.9 to 1.4 kg/m³ in 56 days (i.e. 5.868 to 9.128 kg/m³ in 365 days) obtained by Guerrero (1980) feeding varying levels of fish meal in feed to Oreochromis niloticus in floating cages in the Philippines.

The mean total fish production in treatment IV (groundnut cake in feed) was significantly different from the mean total fish production in all the remaining three treatments ($P < 0.05$).

5.5 CONCLUSION AND RECOMMENDATION

Weatherly and Cogger (1977) had identified cost of protein as a principal obstacle in culture of fish. The series of feeding experiments carried out under

this chapter were aimed at a systematic evaluation of various agricultural and industrial by-products singly and in combination with some other readily available feedstuffs in order to obtain practical diets for the nursery and the grow-out phases of Tilapia (Oreochromis niloticus) cage culture. The data for the conclusion is as summarized in Appendix 2.

Under the nursery-related experiments, it could be concluded that:

(i) Corn bran gave the best FCR (6.5), highest average final weight (1.60g/fish) and the fastest growth rate (0.0102g/d/fish) (Appendix 2).

(ii) The combination of corn bran and brewer's waste (in ratio 1:1) gave the best FCR (4.38), highest average final weight (1.26g/fish) and the fastest growth rate (0.029g/day/fish) and the fastest growth rate (0.029g/day/fish) (Appendix 2).

(iii) The feed containing corn bran with constant amount of fish meal and premix gave the best FCR (1.13), highest average final

(5.01g/fish) and the fastest growth rate (0.1175g/day/fish) (Appendix 2).

Whereas, under the grow-out phase experiments, it could be concluded that:

(i) The feed containing 10% blood meal was the most efficient in terms of average final weight (39.1g/fish), growth rate (0.39g/day/fish) and total fish production (3.910 kg/m^3).

(ii) The feed containing groundnut cake as a major protein source was the most efficient in terms of average final weight (113.1g/fish), growth rate (0.79g/day/fish), FCR (1.12) and total fish production (3.815kg/m^3).

Considering the observations made above, it is recommended that:

(i) for the nursery production of Tilapia (O. niloticus) fingerlings, the feed (in powdered form) containing 25% fish meal, 74% corn bran and 1% premix is efficient for fast growth of fry to fingerlings in net-hapas.

(ii) for the grow-out phase in production of table size Tilapia (O. niloticus), the feed (in pellet form) containing 25% groundnut cake, 74% layer's concentrate/ corn bran (in ratio 1:3) and 1% premix is ideal for fast growth of fingerlings to table-size Tilapia in net-cages.

Since there were large annual crops of cotton in Egypt, cotton seed meal is the principla protein source for feeds in that country (FAO, 1983). Like cotton seed in Egypt, groundnut cake can become a principal protein source for feeds in Nigeria if the "groundnut pyramids" of the norther states of Nigeria can be revitalized through an agrarian revolution. FAO (1983) reported that in Nigeria from an annual groundnut crop of 620,000 tons, more than 380,000 tons of groundnut cake could be made available if all the seeds were crushed for oil. Abundant production of groundnut cake would invariably lead to a reliable solution to the incessant problem of inadequacy of efficient fish feed for fish production.

Since Nigeria has large reserves of petroleum or natural gas, it is also recommended that the possibility of large scale production of single cell protein from these natural resources should be exploited.

CHAPTER 6

6.0 STOCKING DENSITIES EXPERIMENTS USING TILAPIA (Oreochromis niloticus) WITH OR WITHOUT SUPPLEMENTARY FEEDING IN FLOATING CAGES

6.1 INTRODUCTION

Stocking density is usually represented as the number or weight of fish stocked per unit area or volume of the culture medium/space (i.e. in No or kg per m^2 or m^3). Stocking density has been reported to affect survival, growth and production of fish (Alderdice and Gollub, 1971; Steffens, 1971; Konikoff and Lewis, 1974; Wojno, 1976; Beveridge, 1987). The rapid spread of disease among caged fish could be attributed to high stocking densities (Beveridge, 1987). In yellow tail cage culture, mortalities as high as 30% could occur because the fry could be cannibalistic particularly at high stocking densities (Horma, 1980). Beveridge (1987) reported that the stocking density depended on the size of the fish and the prevailing environmental conditions. Fujiya (1979) noted that in yellow tail cage farming, the stocking density increases from a minimum of 7.9kg/m^3 when the fish were first stocked in the grow-out cages at an average weight of 10g per fish, to a maximum of 11kg/m^3 when the fish reached 500g. However, Kafuku and Ikenoue (1983) opined that under ideal conditions, stocking densities (yellow tail) of up to 40kg/m^3 could be achieved. Taniguchi (1983) observed that preventive

measures against mortalities caused by Streptococcus in yellow tail culture included low stocking densities and maintenance of good water quality among others. Escover and Claveria (1985) observed that in cage culture of Tilapia, stocking densities ranged from 5 to 50 fingerlings per m^3 depending on site, cage size, feeding practices and desired size at harvest. Bautista (1984) opined that stocking densities could also change with season and from year to year. Trzebiatowski et al (1981) reported that it was evident that the rainbow trout stocking density might differ depending on environmental conditions, water flow speed and culture system as well as on market requirements.

Most of the above observations on the effect of stocking density on fish production in cages have not been studied in Nigeria. The main objective of this chapter is to determine the effect of stocking density on the survival, growth and production of fish (Tilapia) in the floating cage culture system.

6.2 MATERIALS AND METHODS

For the purpose of comparison the following three experiments were carried out. The first experiment (6.2.1) on stocking densities (25-100/m^3) at Kigera III Reservoir was aimed at determining the effect of rearing the caged fish compared with experiment 6.2.2 involving stocking density (200/m^3

maximum) using a supplementary feed with slightly higher protein content for usual 150-day culture period. The third experiment (6.2.3) however, was to exploit the natural productivity of the Lake (at Intermediate Basin) without supplementary feeding at similar stocking densities as in experiment 6.2.1.

6.2.1 The Effect of Stocking Density (25-100/m³) on Tilapia Production in Floating Net-cages in Kigera II Reservoir

The experiment consisted of four treatments:

i) 25 fish/m³

ii) 50 fish/m³

iii) 75 fish/m³

iv) 100 fish/m³

Each treatment was replicated in three cages (1.0 x 1.0 x 1.5m net-cage size) in a completely randomized design. Tilapia fingerlings, average size 4.6 - 6.7g were randomly stocked in the net-cages early in the morning. The fish were fed with a 17.3% crude protein pelleted feed at 6% of their biomass per day. The fish daily ration was adjusted monthly by sampling 20% of the fish for body weight changes. The fish were harvested after 365 days culture period (16 March 1986 to 15 March 1987). Some physico-chemical parameters of the water at the culture site were also monitored as described under section 3.8.

6.2.2 The Effect of Stocking Density (25-200/m³) on Tilapia Production in Floating Net-Cages in Kiger: III Reservoir

The treatments I, II, III and IV corresponding to 25, 50, 100 and 200 fish/m³ respec ively were assigned to net-cages (1.0 x 1.0 x 1.5m size) using completely randomized design. (reochromis niloticus fingerlings (average weight, 3.5 - 7.0g) were stocked according to the treatments into the cages. Each treatment was replicate. twice. The fish in all the treatments were fed with 18.9% crude protein pelleted feed at 6% of their bi mass twice daily (08.00 and 18.00 hrs). The daily ation of the fish was adjusted monthly after sam ing for growth. The fish were harvested after 150 d s c lture period (16 April - 12 September 198).

6.2.3 The Effect of Stocking Density (25 - 100/m³) on Tilapia Production in Net-Cages at t e Intermediate Basin, NEPA Ka i Dam Site

The site for this experiment had earlier been described under section 3.2.1 (Figure 3.1). Four treatments: I, 25 fish/m³; II, 50 fish/m³; III, 75 fish/m³ and IV, 100 fish/m³ were used in this experiment with no supplementary feeding. The

fish were made to subsist mainly on the natural food in the culture site. Tilapia fingerlings (average size, 15.0 - 19.0g) were stocked into net-cages (1.0 x 1.0 x 1.5m size, 12.7mm mesh) early morning. Each treatment was replicated twice. The fish were sampled monthly for growth. The fish were harvested after 150 days culture period (11 March - August 1988).

6.3 RESULTS

6.3.1 Performances of Tilapia Stocked at Densities of 25 - 100 fish/m^3 in Cages in Kigera III Reservoir

6.3.1.1 Survival

The survival rates recorded in this experiment were high: treatment I, 93.9%; treatment III, 90.2%; treatment II, 89.0% and least in treatment IV, 77.5% (Table 6.1). The average survival rate for all the four treatments was 87.7%. Table 6.2 shows the results of some physico-chemical parameters of the reservoir during the experiment.

6.3.1.2 Growth

The growth rate (g/fish/day) was highest in treatment I (0.34), followed by treatment II (0.22), then treatment III (0.19) and least in treatment IV (0.16) (Table 6.1). It was observed that the growth rate of the fish generally decreased with the increase in stocking density.

Table 6.1: Results for Tilapia sp stocked in Cages at Different Densities for 365 Days Culture Period at Kigera III Reservoir, New Dussa

Treatment	Average Wt. (g) Initial	Average Wt. (g) Final	Average Daily Wt. gain (g/d)	Survival (%)	Production (kg/m³)
I 25/m³	4.9	100.0	0.26	95.0	2.376
	5.6	150.0	0.40	94.4	3.465
	5.4	133.3	0.35	94.3	3.143
	5.3	127.8[a]	0.34[a]	93.9[a]	2.994[b]
II 50/m³	6.8	97.2	0.25	91.2	4.432
	6.2	64.7	0.16	88.9	2.847
	7.1	100.0	0.25	87.8	4.390
	6.7	87.3[b]	0.22[b]	89.0[b]	3.889[ab]
III 75/m³	4.8	72.5	0.19	90.0	4.894
	5.4	74.0	0.19	89.5	4.967
	5.4	79.2	0.20	91.1	5.411
	5.2	75.2[b]	0.19[b]	90.2[bc]	5.091[a]
Iv 100/m³	4.8	58.7	0.15	75.8	4.449
	4.5	71.7	0.18	80.2	5.750
	4.5	61.4	0.16	76.5	4.697
	4.6	63.9[b]	0.16[b]	77.5[d]	4.965[a]

Means in a column with the same superscript are not significantly different at 5% DMRT

Table 6.2: Range and Mean of Physico-chemical Parameters of Kigera III Reservoir During the Experimental Period

Parameter	Range	Mean
Temperature (°C):		
Air	26.0-40.0	30.5
Water	23.0-38.0	30.5
pH	7.1- 7.5	7.3
Dissolved Oxygen (mg/l)	4.0- 6.8	5.4
Transparency (m)	0.30-0.40	0.10
Conductivity (µmhos/cm)	250-320	285

6.3.1.3 Production

The total fish production (kg/m³) was highest in Treatment III (5.091), followed by Treatment IV (4.965 then Treatment II (3.889) and least in Treatment I (2.994). Unlike in the case of growth rates (and average final weight per fish), the total fish production generally was directly related to the stocking densities - the production increasing with increasing stocking density (Table 6.1) except for Treatment III (7[illegible] fish/m³).

6.3.2 Performances of Tilapia Stocked at Densities of 25 - 200 fish/m³ in Kigera III Reservoir

6.3.2.1 Survival

The survival rates recorded in the experiment were generally very high: Treatment I, 100%; Treatment II, 99.5%; Treatment III, 99.0% and least in Treatment IV, 94.5% (Table 6.3). The survival rates were observed to decrease gradually as the stocking density increased (inverse relationship).

6.3.2.2 Growth Rates

The mean daily weight gain of the fish under the different treatments is shown in Table 6.3. The mean growth rates (g per fish per day) for treatments I, II, III and IV were 0.48, 0.43, 0.36 and 0.21 respectively.

Table 6.3: Results for Tilapia sp. Production at Different Stocking Densities in Floating Cages at Kigera III Reservoir for 150 Days Culture Period

Treatment	Average Wt. (g)		Average Daily Wt. gain (g/d)	Survival (%)	Total Production (kg/m³)
	Initial	Final			
I 25/m³	8.4 5.6 7.0	78.9 79.1 79.0[a]	0.47 0.49 0.48[a]	100.0 100.0 100.0[a]	1.973 1.978 1.976[a]
II 50/m³	6.0 5.0 5.5	63.0 75.5 69.3[ad]	0.38 0.47 0.43[ad]	100.0 99.0 99.5[a]	3.150 3.737 3.444[a]
III 100/m³	7.2 6.1 6.7	58.2 61.6 59.9[bd]	0.34 0.37 0.36[bd]	99.0 99.0 99.0[a]	5.762 6.098 5.930[b]
IV 200/m³	5.5 5.9 5.7	40.0 34.4 37.2[c]	0.23 0.19 0.21[c]	96.0 93.0 94.5[b]	7.680 6.398 7.039[c]

Means in a column with the same superscript are not significantly different at 5% DMRT

6.3.2.3 Production

The total fish production values (kg.m^{-3}) in the experiment were 1.976, 3.444, 5.930 and 7.039 for Treatments I, II, III and IV respectively (Table 6.3). The production was observed to increase with increase in the stocking density.

6.3.3 Performances of Tilapia stocked at Densities of 25 - 100 Fish/m^3 in Cages (without feeding) at Intermediate Basin, NEPA Kainji Dam Site

6.3.3.1 Survival

The survival rates of O. niloticus stocked at different densities without supplementary feeding are shown in Table 6.4. The survival rates were generally low, ranging from 18.0% for Treatment I to 47.0% for Treatment III. Table 6.5 shows the results of some physico-chemical parameters of the Basin during the experiment.

6.3.3.2 Growth Rates

Table 6.4 shows the growth rates of the fish under the different stocking densities at Intermediate Basin of NEPA Kainji Dam Site. The growth rates were 0.27g/fish/day in treatment II; 0.31g/fish/day in both treatments III and IV; and highest in treatment I (0.39/fish/day).

Table 6.4: Results for Tilapia Production at Different Stocking Densities (without supplementary feeding) in Floating Net-Cages at Intermediate Basin, NEPA Kainji Dam Site for 150 Days

Treatment	Average Weight (g)		Average Daily Wt Gain (g/d)	Survival (%)	Total Production (kg/m³)
	Initial	Final			
I 25/m³	18.0 16.0 17.0	61.5 89.5 75.5[a]	0.29 0.49 0.39[a]	8.0 28.0 18.0[a]	0.123 0.627 0.375[a]
II 50/m³	19.0 16.0 17.5	74.5 41.5 58.0[a]	0.39 0.17 0.27[a]	44.0 16.0 30.0[a]	1.639 0.332 0.986[a]
III 75/m³	17.0 17.0 17.0	65.0 62.0 63.5[a]	0.32 0.30 0.31[a]	47.0 47.0 47.0[a]	2.291 2.186 2.239[a]
IV 100/m³	15.0 15.0 15.0	54.0 69.0 61.5[a]	0.26 0.36 0.31[a]	31.0 62.0 46.5[a]	1.674 4.278 2.976[a]

Means in a column with the same superscript are not significantly different at 5% DMRT.

Table 6.5: Ranges and Means of Physico-chemical Parameters of Intermediate Basin, NEPA Kainji Dam Site During the Experimental Period

Parameter	Ranges	Means
Water Temperature (°C)	28.6-29.8	29.0
pH	7.8- 8.2	8.0
Dissolved Oxygen (mg/l)	6.4- 8.6	7.5
Transparency (m)	0.43-0.77	0.6
Conductivity (µmhos/cm)	65-82	73

6.3.3.3 Production

The total fish production (kg/m³) during the 150-day culture period were 0.375, 0.986, 2.239 and 2.976 for Treatments I, II, III and IV respectively (Table 6.4). In spite of the low survival rates as explained earlier, the total fish production was observed to have a direct relationship with the stocking densities, i.e. the total fish production increased as the stocking densities increased.

6.4 DISCUSSION

6.4.1 Performances of Tilapia Stocked at Densities of 25 - 100 Fish/m³ in Cages in Kigera III Reservoir

6.4.1.1 Survival

The average survival rate in this experiment was higher than the average survival rates of 62.5% and 74.2% recorded for O. niloticus stocked at densities (50 - 100/m³) in running water and standing water respectively by Ishak (1987).

Considering the duration of culture (365 days), O. niloticus at the varying densities stocked were able to adapt to the culture environment and survive in the cages. There were significant differences between the mean survival rates in the treatments ($P < 0.05$) (Table 6.1).

6.4.1.2 Growth Rates

It is often stated that the degree to which fish are crowded together will affect growth (Weatherly, 1972). A similar relationship (inverse relationship between stocking density and growth rate) has been reported by Albrecht and Gollub (1971) and Wojno (1976). Wedemeyer (1976) opined that at high fish stocking densities, the freedom of movement and feeding are hampered, thus the availability of food, even when the latter is offered in excess, becomes a limiting factor.

At the stocking density of 50 fish/m^3, the fish growth rate, 0.34g/fish/day was higher than the growth rate, 0.17g/fish/day in running water at a similar stocking density (50/m^3) reported by Ishak (1987).

The growth rate in Treatment I was observed to be significantly different from those of the other treatments ($P < 0.05$) (Table 6.1).

6.4.1.3 Production

The fish production in all the treatments were generally lower than 0.9 to 1.4kg/m^3 in 56 days (i.e. 5.868 to 9.128 kg/m^3 in 365 days) in cages obtained by Guerrero (1980) using O. niloticus (100 fish/m^3) but feeding 25 to 35% fish meal in pelleted feed. On the other hand, with no supplementary feeding, Ishak (1987) reported a total production of 0.782kg/m^3 in 150 days (i.e. 1.902kg/m^3 in 365 days) stocking O. niloticus at 50/m^3 in running water. He concluded that the low fertility of the water among other causes

was responsible for the relatively low production and that the natural fertility of a given water body was an important factor to be considered for increased production of O. niloticus. This is further supported by Warren (1971) who opined that growth (also a factor related to production) as a response to the integrated activities of an organism as a whole is a sensitive parameter of the suitability of the environment. The generally slow growth (hence total production) of the fish in this experiment may be attributed to low productivity of Kigera III Reservoir. Plankton production has already been reported to be relatively low in the reservoir (Abohweyere, 1990). However, there were significant differences between the means of total fish production under the different treatments ($P < 0.05$):

6.2 Performances of Tilapia Stocked at Densities of 25 - 200 Fish/m³ in Cages in Kigera III Reservoir

6.2.1 Survival

The range of survival rates (94.5% to 100.0%) under the stocking densities 25 - 200/m³ was higher than the range 77.5% to 93.9% recorded when O. niloticus was stocked at between 25 and 100 fish/m³ in section 6.3.1. This observation corroborates that of Lewis (1969) who reported that many fishes would fight when confined in moderate densities (25 to 75 fish per m³), but these same fish would thrive at higher densities (200 to 300 fish per m³).

In addition, the high survival rates could be attributable to the favourable physico-chemical parameters of the culture medium (Table 6.2). The ranges of the physico-chemical parameters recorded during the period of the experiment were within the tolerable ranges for Tilapia (Swingle, 1975; Balarin, 1979; Guerrero, 1982). However, the mean survival rate recorded under Treatment IV (200 fish/m^3) was significantly different ($P < 0.05$) from those of all the other three Treatments (Table 6.3).

6.4.2.2 Growth Rates

The observation showed an inverse relationship between the stocking densities and the growth rates, i.e. as the stocking densities increased, the growth rates decreased. This is similar to the observation of Trzebiatowski et al. (1981) who reported that for rainbow trout (Salmo gairdneri) individual growth rate and natural losses were inversely proportional to stocking densities.

The range of the mean growth rates (0.21 to 0.48g/fish/day) in this experiment (Table 6.3) was higher than the range, 0.16 to 0.34 g/fish/day recorded at the stocking densities range of 25 to 100 fish per m^3 (Table 6.1). In spite of the fact that the initial total fish biomass per treatment (average 565.0g/m^3) for the stocking densities (25 - 200 fish/m^3) (Table 6.3) was

higher than the initial total fish biomass per treatment (average 329.4g/m^3) for 25 - 100/m^3 (Table 6.1), the mean growth rates for the Treatments (25 to 200 fish/m^3) were still higher than for the Treatments (25 to 100 fish/m^3).

The fact that the fish stocked at higher densities (25 to 200/m^3) and higher biomass (175.0 to 1140.0g/m^3) still grew faster than those stocked at lower densities (25 to 100/m^3) proved that the culture site was still capable of sustaining the growth of the fish; i.e. the carrying capacity of the medium had not been exceeded. Hickling (1971) noted that the carrying capacity also referred to as maximum standing crop would vary with the water supply. He further stressed that fish could be very densely stocked in cages because they are in flowing water and so run no risk of asphyxiation. This is further confirmed by Bardach et al. (1972) who noted that even though fish in cages are physically restrained in a very small area, the amount of clean, oxygenated water available is theoretically unlimited. Bardach et al. (1972) therefore elucidated that in Japan while Chinese carp fry were stocked at 1,400 to 1,800/m^2 in pond the fry were stocked at 15,000 to 62,000/m^2 in net-cages. Coche (1982) therefore concluded that the maximum carrying capacity of a cage (in kg/m^3) is mainly determined by the dissolved oxygen concentration throughout the cage.

Since the size range of fingerlings (5.5 to 7.0g) stocked in this experiment (Table 6.2) was similar to the size range (4.6 to 6.7g) stocked in the experiment under section 6.3.1, the marked difference in the growth rates of fish in the comparable stocking densities (25, 50 and 100 fish/m²) could be attributed to the food (natural and artificial) available to the fish in the environment. The quality of the pelleted feed (18.9% crude protein, made up of 10% blood meal, 89% corn bran and 1% premix) fed to fish in this experiment could have contributed to the faster growth rates of the fish compared to the 17.3% crude protein feed (consisting of 40% brewer's waste, 43.5% corn bran, 14.5% layers concentrate and 2.0% starch as binder) fed to fish in the experiment under section 6.3.1.

However, the mean growth rate of fish under Treatment I was significantly different ($P < 0.05$) from the mean growth rates under Treatments II, III and IV.

6.4.2.3 Production

The observation in this experiment is similar to that of Trzebiatowski et al. (1981) on rainbow trout. The range of total fish production in this 150-day experiment (1.976 to 7.039kg/m³; average, 4.597kg/m³) is better than the range (2.994 to 5.091 kg/m³; average, 4.2351 g/m³) recorded in the 365-day experiment under section6.3.1. Generally, the total fish production in this experiment were higher than the range 1.6 to 2.4

kg/m³ obtained by Garcia (1979) and Guerrero (1979) stocking S. mossambicus fingerlings (5-10g) average weight at 16 fish/m³ for a 6-month culture period. Considering the treatment with 100 fish/m³, the total fish production is quite low compared to the total fish production values of between 10.5 and 15.8 kg/m³ obtained by McLarney (1978) and Popma (1978) stocking Tilapia rendalli (average size 24.8g) at 100 fish/m³ for between 3 months + to about 7 months. In the Philippines, Guerrero (1979) reported a total fish production of 25.0kg/m³ stocking S. niloticus (average size 20g) at 250 fish per m³ and fed 24.2% dry weight of protein for 2 months. This production is definitely higher than the value 7.039kg/m³ obtained under Treatment IV (200 fish/m³) in this experiment. In Ivory Coast, Campbell (1978) obtained a total fish production range of 13.3 to 49.9 kg/m³ feeding 20% protein feed to S. niloticus (average 84 males, average size, 26g) stocked at between 71 to 185 fish/m³ in Lake Kossou for between 108 and 131 days culture period. This total fish production range is definitely higher than the range 1.976 and 7.039kg/m³ obtained in this experiment even though under a mixed sex culture.

Since growth is a factor directly related to production, the growth rates of 0.37 to 0.79g/fish/day obtained from feeding pelleted feed of different protein sources (Table 5.13) to O. niloticus stocked at 50 fish/m³ evidently proved that a well balanced feed will result

in faster growth rate and hence higher fish production even at higher fish stocking densities. For example, Suwanasart (1972) reported growth rates of 0.72 to 1.72g/day and total fish production of 54.8 to 83.3kg/m^3 feeding 40% protein feed (floating or sinking) to S. aureus (25g average size) stocked at 500 fish per m^3 in a 3-month culture period. Armbrester (1972) similarly fed 40% protein feed to S. aureus (average size, 2.9g) at 600 fish/m^3 and obtained a growth rate of between 0.56 to 0.76 g/day and a total fish production of 56.4 kg/m^3 in 2.5 months but in the presence of moderate plankton blooms. The mean weight per fish at harvest obtained by Armbrester (1972) ranged between 39 and 73g and was comparable to the values 37.2 to 79.0g recorded under this experiment. It was interesting to note that Pagan (1973) feeding 40% protein to S. aureus (average size, 13g) stocked at 857 fish/m^3 obtained a growth rate of 1.039g/fish/day; average final weight per fish at harvest, 174g and a total fish production of 149kg/m^3 in a 5.2-month culture period. This observation further confirmed the role of artificial feed (especially complete feed) in intensive, high density cage fish culture (Campbell, 1985).

However, there were significant differences ($P < 0.05$) between the mean total fish production values under the different treatments.

6.4.3 Performances of Tilapia Stocked at Densities of 25 - 100 Fish/m³ in Cages (without feeding) at Intermediate Basin, NEPA Kainji Dam Site

6.4.3.1 Survival

The survival rates were generally low, not because the fish could not survive but they were lost as a result of leakage in most of the cages which were fairly old. The fairly old net cages could have been gnawed at by the herbivorous fish (including the stocked Tilapia which were not supplementarily fed). Some of the stocked fish therefore escaped through the holes made in the cage walls especially at the bottom corners. Since the fish loss was first observed after 2 months culture period and also when algal growth had covered the twines of the nylon net-cages, it was likely that herbivorous fish (including the stocked Tilapia) had been attracted to the algae covering the twine and gnawed at both the twine and the algae. A similar problem (gnawing at net-cage) had been reported in Israel by Ben Yami (1974) in the cage-rearing of a herbivorous rabbit fish (Siganus rivulatus). He noted that as a result many fish escaped. The physico-chemical parameters (Table 6.5) recorded during the experimental period were within favourable limits as recommended for Tilapia by Swingle (1961), Balarin (1979) and Guerrero (1982). In fact, Adeniji and Ita (1976) having carried out a limnology and fisheries investigation of the Intermediate Basin for recreational fishing concluded that generally

the limnological characteristics of the basin (i.e. water temperature, D.O, Water Transparency and Plankton) were favourable to good growth and survival of fish. There were no significant differences ($P > 0.05$) between the mean survival rates under the different treatments.

6.4.3.2 Growth Rates

Even though the stocked fish subsisted solely on natural food in the water medium, the range of growth rates (0.27 to 0.39g/fish/day) was better than the range (0.16 to 0.34g/fish/day) recorded under similar stocking densities of O. niloticus fed with supplementary feeds in net-cages at Kigera III Reservoir (Table 6.1). Since the fish in all the treatments grew well, it could be concluded that the natural productivity of the water (at the Intermediate Basin) was adequate to sustain the fish in the cages. Adeniji and Ita (1976) had earlier observed that the species of plankton in the basin were similar to those present in the lake (Lake Kainji). Good growth of O. niloticus had earlier been reported in a mixed species cage culture of fish (at Shagunu Bay also located on Lake Kainji) with little or no supplementary feeding (Table 4.3). Coche (1982) reported an average growth rate of 0.89g/fish/day for S. mossambicus (average size 6g) stocked at 25 to 75 fish/m^3 without supplementary feeding at Laguna de Bay (a hypereutrophic Lake) in the Philippines. Extensive commercial Tilapia farming utilizing the natural

productivity of Laguna Lake has been reported by Santiago (1982); Escover and Claveria (1985); Lazaga and Roa (1985). Although when first exploited, Laguna de Bay was sufficiently productive to support high densities of fast growing fish without recource to the use of feeds (PCARRD, 1981; Coche, 1982). However, Beveridge (1984) reported that this Lake (Laguna) had been rapidly over-exploited as a result of over-crowding of fish cages. In Singapore, Yang (1982) reported the successful use of cages of big head carp at several reservoirs to control excessive plankton blooms in municipal water supplies.

Frequent occurrences of algal blooms have been reported in Lake Kainji especially during the month of October (Adeniji, 1973). Extensive Tilapia cage culture as observed in the Intermediate Basin can in addition benefit from this period of high phytoplankton densities in Lake Kainji.

Furthermore, the average weight of fish (average 16.6g) stocked under this experiment (Table 6.4) seem to be advantageous in the comparable good growth rate recorded considering the average size of 5.5g stocked under similar stocking densities (25-100/m^3) in Kigera III Reservoir (Table 6.1). This corroborates the report of Ishak (1985) who observed that the cage culture of common carp showed that the size of fish at stocking was a limiting factor for production/m^3. He noted that when common carp were stocked at an initial

average size of 27g/fish, maximum production rate of 20kg/m³ was obtained in a 4m³ cage at a stocking density of 160 fish/m³ while when the stocking size was 95g/fish, maximum production rate was 32.5kg/m³ at a stocking density of 60 fish/m³.

6.4.3.3 Production

Since the average final (at harvest) weight/fish has a directly relationship with the total fish production, in 365 days the estimated average final weight per fish in the Intermediate Basin would have been 157.2g compared to 88.6g recorded under similar stocking densities (but with supplementary feeding) in Kigera III Reservoir. But for the leakage in the cages which resulted in serious fish loss (hence low survival rates), the total fish production at the Intermediate Basin under the extensive culture would have been quite high (an average of 14.148 kg/m³ per year assuming 90% survival and 157.2g/fish). Coche (1982) noted that the maximum carrying capacity (MCC) of a cage (in kg/m³) is mainly determined by the dissolved oxygen throughout the cage. He noted that MCC varies with the mesh size and cage size. The water in the cages during the experimental period was observed to be well oxygenated (average D.O., 7.5mg/l, Table 6.5). Considering the mesh size and cage size, Campbell (1978) has defined the MCC (in kg/m³) for S. niloticus reared in well-oxygenated water with good circulation (at least 2 cm/sec) as follows; with plastic netting 2mm mesh, 90 for 1 m³, 70 for 6 m³ and 40 for 20 m³;

with nylon fibre netting of 14 mm mesh, 40 for 20m³ Therefore as cage size increases, MCC decreases. Since a nylon fibre netting of 12.7 mm mesh and cages size 1.0 x 1.0 x 1.5m were used in the Intermediate Basin experiment, based on the definition of MCC by Campbell (1978), the MCC of the cages could be higher than 40 kg/m³.

6.4 CONCLUSION AND RECOMMENDATION

Even though the best size of fish (at harvest) 127.8g was observed under Treatment I (25 fish/m³) of experiment 6.2.1; based on the total fish production and the survival rate, Treatment III (75 fish/m³) was found to be the best under the prevailing conditions and management applied at Kigera III Reservoir during the culture period (365 days).

It can be concluded that high quality supplementary feed is necessary in increasing production especially at higher fish stocking density as shown by the results under experiment 6.2.2.

In the Intermediate Basin experiment without supplementary feeding, treatment IV stocked with 100 fish/m³ had the best total fish production (2.976 kg/m³ in 150 days). It could also be concluded that natural productivity of the Intermediate Basin was capable of sustaining good growth of fish even at an initial density of 100 fish/m³ (or 1.5kg/m³) without supplementary feeding.

From the above conclusions, it could be recommended that:

(i) because of the low productivity of Kigera III Reservoir, a good quality pelleted feed (minimum of 20% crude protein) is needed for good growth of C. niloticus at a stocking density of 200 fish/m³ (or 1.14kg/m³). For a faster growth and higher total fish production, large size of fingerlings (about 20g/fish) must be stocked.

(ii) In the productive Intermediate Basin, extensive cage culture of Tilapia should be encouraged. It may prove to be a viable alternative to the management of a resource as a fishery and it may be prudent to carry out some extensive culture of fishes in cages in conjunction with intensive lake-based fish rearing. This will reduce the environmental impact of wastes whilst increasing the profitability of the venture. Obviously, extensive cage culture in Lake Kainji should be of value for the rural communities.

Furthermore, it may be advisable to switch between semi-intensive and extensive cage culture at different times of the year, so as to take advantage of period of algal blooms in the lake. To date, there is no single private commercial cage culture on Lake Kainji.

CHAPTER 7

7.0 BREEDING EXPERIMENTS USING DIFFERENT MALE : FEMALE RATIOS OF OREOCHROMIS NILOTICUS BREEDERS AND HYBRIDIZATION TRIALS USING OREOCHROMIS NILOTICUS AND SAROTHERODON GALILAEUS IN FLOATING NET-HAPAS

7.1 INTRODUCTION

7.1.1 Tilapia Seed Production Experiment

Productive fish culture, like in terrestrial animal husbandry is heavily dependent upon adequate supply of good quality seed. One of the major constraints to increased fish production through Tilapia cage culture has been identified to be inadequate supply of the fish seed (Coche, 1982). Coche (1977 and 1979) opined that existing Tilapia breeding practices were inadequate and a new technology should be developed for selected tilapias.. Several methods have been used to produce Tilapia seed (Shell, 1966; Radan, 1979; Guerrero and Garcia, 1983; Hughes and Behrends, 1983; Beveridge, 1984). Hughes and Behrends (1983) working on mass production of Tilapia nilotica seed in suspended net-enclosures concluded that the hapa system for T. nilotica appears to be more productive than most other systems..

Among factors considered to be important in fish seed production are brood fish age and size,

brood fish stocking density, brood fish sex ratio, brood fish nutrition, frequency of removing brood fish and/or seed from the brooding unit, types of container, water quality and rate of water exchange (Silvera, 1978; Berrios-Hernandez, 1979; Lee, 1979; Coche, 1982; Mires, 1982).

Research Scientists of South East Asian Fisheries Development Centre(SEAFDEC), Laguna Lake Development Authority (LLDA), and various Universities, since the late 1970s and early 1980s experimented (considering breeders sex ratio, density, etcetera) with lake-based hatcheries and nurseries (net-hapas) such that today, there are several commercial lake-based and Tilapia fry and fingerlings units in operation on some major lakes in the Philippines (SEAFDEC, 1982; 1982; Beveridge, 1987). By this approach, the Tilapia fingerlings needs of that country were being met as much as possible.

In Nigeria, there is no record of such experiments in the use of lake-based hatcheries and nurseries utilizing net-hapas for tilapia seed production in spite of the immense potentials of Tilapia cage culture in the country (Otubusin, 1983; 1989).

7.1.2 Hybrid Tilapia (seed) Production Experiment

Within the genera Tilapia, Sarotherodon and Oreochromis there are numerous species of which only a few have been used for culture work. In Lake Kainji, Nigeria, Sarotherodon galilaeus is the most abundant of the tilapias, followed by Oreochromis niloticus (Johnson, 1974; Akintunde, 1976). The latter was observed to have a better growth rate than the former (Bardach et al., 1972).

In most Tilapia species, it has also been observed that the male grows faster than the female (Fryer and Iles, 1972). Guerrero (1985) opined that the faster growth of Tilapia hybrids over their parent stocks may be partly explained by the higher percentage of males in the former. In recent years, S. hornorum has become a popular species for transplantation because of its suitability for the production of all-male hybrids (Lovshin and Da Silva, 1975). Some work has been done on the hybridization of tilapia species (Bard, 1960; Elder and Garrod, 1961; Fishelson, 1962; Kuo, 1969; Al-Daham, 1970; Chen and Tsuyuki, 1970; Hine et al., 1971; Lovshin and Da-Silva, 1975; Mires, 1977; Lee, 1979; Hsiao, 1980; Bautista et al., 1981; Abella, 1982) and particularly on the interspecific cross Sarotherodon (Oreochromis) niloticus x Sarotherodon galilaeus (Wohlfarth and

Hulata, 1981). These studies, however, were reportedly carried out in tanks or aquaria (Mires, 1982). Wohlfarth and Hulata (1981) also reported that crosses between S. galilaeus and maternal mouth brooders have recently been carried out artificially.

Also in line with the general aims and objectives of this study on fish seed production in cage system, experiments were designed and conducted to determine the effect of hybridization of Sarotherodon galilaeus and Oreochromis niloticus (locally available commercially important Tilapia species) on the spawning frequency and fry production potential (the number and growth) in the floating net-hapa system in a drinking water reservoir (Kigera III).

7.2 MATERIALS AND METHOD

7.2.1 The Effect of Male : Female Ratio of Oreochromis niloticus breeders on fry production in floating net-hapas

This experiment was carried out in Kigera III Reservoir (Figure 3.1), already described under section 3.2. A module consisting of a 6m x 6m raft with 16, 1.25m x 1.25m apartments fittable with 1m x 1m net-hapas was used (Plate IV). The construction procedures for raft and hapas are as described under sections 3.3.1.2 and 3.3.2.1 respectively. The experiment consisted of three

treatments: I, 1 male : 1 female (12/m^3); II, 1 male : 3 females (12/m^3); III, 1 male : 5 females (12/m^3). The breeders (average weight, 124.2g for males and 66.2g for females) were sexed as described for Sarotherodon mossambicus by Maar et al. (1966) and stocked randomly in net-hapas late evening (between 20.00 - 22.00 hr) according to the treatments above on 2 April, 1986.

The breeders were fed with 50% blood meal in pelleted feed (49.07% protein) twice daily at 5% of their biomass. The composition and proximate analysis of the feed are as described under section 5.2.4 (Tables 5.10 and 5.11). The procedures for the fish feed preparation and fish feed proximate composition determination also are as described under sections 3.5 and 3.6 respectively. Sampling for the number of hatchlings (fry) per hapa was carried out immediately the fry were observed to be schooling within the hapa. The breeders were transferred to a holding hapa in order to facilitate the harvest and counting of the fry. The breeders were later restocked in their initial hapa to continue the breeding experiment. However, the fry were held in separate hapas for nursing to fingerling size.

The breeders were also sampled every month for changes in body weight (growth) and the feed ration

was adjusted accordingly. Some physico-chemical parameters of the water at the site of the experiment were monitored as described under section 3.8.

7.2.2 Experiments on the Hybridization of Oreochromis niloticus and Sarotherodon galilaeus in floating net-hapas

The experiments were carried out in Kigera III Reservoir (Figure 3.1), which had earlier been described under section 3.2. A module of 6m x 6m bamboo raft with 16, 1.5m x 1.5m apartments fittable with 1.0m x 1.0m net-hapas was used for these experiments. The construction procedures for the raft and the net-hapas are as described under sections 3.3.1.2 and 3.3.2. respectively.

A short preliminary run (1st experiment) using S. galilaeus (SAG) and O. niloticus (ORN) was made prior to the actual experiments (2nd and 3rd experiments). The breeders used in these experiments were obtained by beach-seining at Monai Bay (about 5 km away from Bogongari Bay along Lake Kainji, Figure 3.1). The breeders were acclimatized in large holding net-cages (3m x 3m x 2.75m) the type described in Figure 3.6c and Plate VI. During the two-week acclimation period, the breeders were fed sparingly with pelleted feed. The fish species, S. galilaeus (SAG) and O. niloticus (ORN) (Plates vii and viii respectively) had earlier been described under section 3.4. Their breeders (average weight,

ORN: Male, 113.4g; Female, 46.1g and SAG: Male, 103.4g; Female, 36.4g) were sexed as described for Sarotherodon mossambicus by Maar et al. (1966). The breeders were stocked randomly in net-hapas (1m x 1m x 1m) in the early morning (between 06.00 - 08.00 hr) of 3 April, 1987 (for the preliminary run i.e. 1st run), and 13 June, 1987 and 6 February, 1988 for the 2nd and 3rd experiments respectively. The following treatments were used:

I. All ORN breeders, 1 male : 3 females ($12/m^3$)

II. All SAG breeders, 1 male : 3 females ($12/m^3$)

III. ORN males : SAG females in the ratio 1 : 3 ($12/m^3$)

IV. SAG males : ORN females in the ratio 1 : 3 ($12/m^3$).

The breeders were fed 10% blood meal in pelleted feed (31.34% protein, Tables 5.1 and 5.11, as described under section 3.5) twice daily at 5% of their biomass. Sampling for the number of hatchlings (fry) per hapa was done immediately after fry were observed to be schooling within the hapa.

The fry from the 2nd experiment (each first spawning) were then transferred to nursery hapas and stocked at the rate of 20/hapa (1m x 1m x 1m size) and fed finely ground (powdered) corn bran at

the rate of 20% of their biomass to study their growth potential. The fish were only sampled at stocking and at harvest (end of culture period) in order to avoid any mortality as a result of sampling stress.

Some physico-chemical parameters of the water at the culture site were monitored during the experimental period as described under section 3.8.

7.3. RESULTS

7.3.1 The Effect of Male : Female ratio of Oreochromis niloticus breeders on fry production in floating net-hapas

The results of some physico-chemical parameters of the water during the fry production experiments are shown in Table 7.1. Table 7.2 shows the summary of results of the effect of male : female ratio of O. niloticus breeders on fry production in floating net-hapas. School of fry was first observed 18 days after stocking in treatment II (M : F, 1 : 3) but 38 and 61 days after stocking in treatments III (M : F, 1 : 5) and I (M : F, 1 : 1) respectively. The highest total fry production was recorded in treament II (2001), followed by treatment I (1800) and least in treatment III (670). But the highest number of spawnings took place in treatment II (4 times), followed by treatment III (2 times) and least in treatment I (only once). The average number of fry per spawn in treatments I, II and III were 1800,500 and 335 respectively while the average

Table 5.8 Summary of results for Oreochromis niloticus receiving different agro-industrial bye-products added to constant amount of fish meal (FM) and premix for a period of 42 days in floating net-hapas

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival Rate (%)
I					
Corn bran + FM + Premix	0.06	4.80	0.1129	1.06	73.0
	0.08	5.21	0.1221	1.19	83.0
	0.07	5.01ab	0.1175a	1.13a	78.0a
II					
Rice bran + FM + Premix	0.13	4.59	0.1062	1.41	66.0
	0.06	5.43	0.1279	1.17	87.0
	0.10	5.01a	0.1171ab	1.29b	76.5a
III	0.09	4.11	0.0957	1.30	86.0
Brewer's waste + FM + Premix	0.05	4.02	0.0936	1.16	67.0
	0.07	4.10abc	0.0960abc	1.23c	76.5a
IV					
Corn bran + Rice bran + Brewer's waste (1:1:1) + FM + Premix	0.03	3.93	0.0928	1.24	75.0
	0.06	3.43	0.0802	1.10	95.0
	0.05	3.68c	0.0865c	1.17d	85.0a

Means in a column with the same superscript are not significantly different at 5% DMRT

FM = Fish meal.

5.3.3.3 Feed Conversion Ratio (FCR)

The best feed conversion ratio, 1.13 was recorded under treatment I, followed by treatments IV, III and II which were 1.17, 1.23 and 1.29 respectively.

5.3.4 Growth performance of Tilapia (Oreochromis niloticus) fed different levels of blood meal in pelleted feeds in floating cages

5.3.4.1 Survival rates

Table 5.9 gives the results of some physico-chemical parameters of the reservoir during this experiment. Generally, the survival rates under this experiment were very high. Treatment III (10% blood meal in pelleted feed) had the best survival rate 100%; closely followed by treatment I (50% blood meal in pelleted feed) 99.5% and treatment II (25% blood meal in pelleted feed), 99.0% (Table 5.10).

5.3.4.2 Growth rates

The results of the proximate analysis of the blood meal feeds are shown in Table 5.11. The growth curves for the fish (O. niloticus) fed on these diets are shown in Figure 5.3. Fish in treatment III (31 34% crude protein containing 10% blood meal in pelleted feed) consistently grew

Table 5.9 Range and mean of some physico-chemical parameters of Kigera III Reservoir during the period of the experiment 5.2.4

Parameter	Range	Mean
Temperature (°C):		
Water	25.8 - 31.6	29.4
Air	26.5 - 32.5	30.5
pH	6.9 - 7.6	7.1
D.O (ppm)	2.9 - 4.8	3.6
Conductivity (umhos/cm)	63 - 160	124

Table 5.10 Summary of results for Oreochromis niloticus receiving different levels of blood meal in pelleted feeds in floatin cages for 120 days.

Treatment	Average Wt. (g) Initial	Final	Average Wt. gain (g)	Relative Wt. gain (%)	Survival Rate (%)	FCR	Total Fish Prodn (kg/m³)
I	3.1	15.0	11.9	383.9	99.0	2.84	1.485
50% Blood meal	3.7	25.0	21.3	575.7	100.0	1.49	2.500
	3.4	20.0a	16.6a	479.8a	99.5a	2.17a	1.993a
II	3.2	25.0	21.8	681.3	99.0	1.81	2.475
25% Blood meal	3.3	45.0	41.7	1263.6	99.0	0.91	4.455
	3.3	35.0a	31.8a	972.5a	99.0a	1.36a	3.465a
III	3.5	44.4	40.9	1168.6	100.0	1.19	4.440
10% Blood meal	4.0	33.8	29.8	745.0	100.0	2.14	3.380
	3.8	39.1a	35.4a	956.8a	100,0a	1.67a	3.910a

* Relative Wt. gain (%) = $\frac{\text{(Final Average Wt. - Initial Average Wt.)}}{\text{Initial Average Wt.}} \times 100$

Mean in a column with the same superscript are not significantly different at 5% DMRT.

Table 5.11 Proximate analysis of the three blood meal feeds (%)

Feed	Crude Protein	Crude Fat	Crude Fibre	Ash	NFE	Ca	P
I	49.07	0.61	3.60	5.31	41.41	1.14	0.07
II	46.87	0.25	3.71	6.81	42.36	1.36	0.11
III	31.34	1.26	4.14	5.90	57.36	1.30	0.10

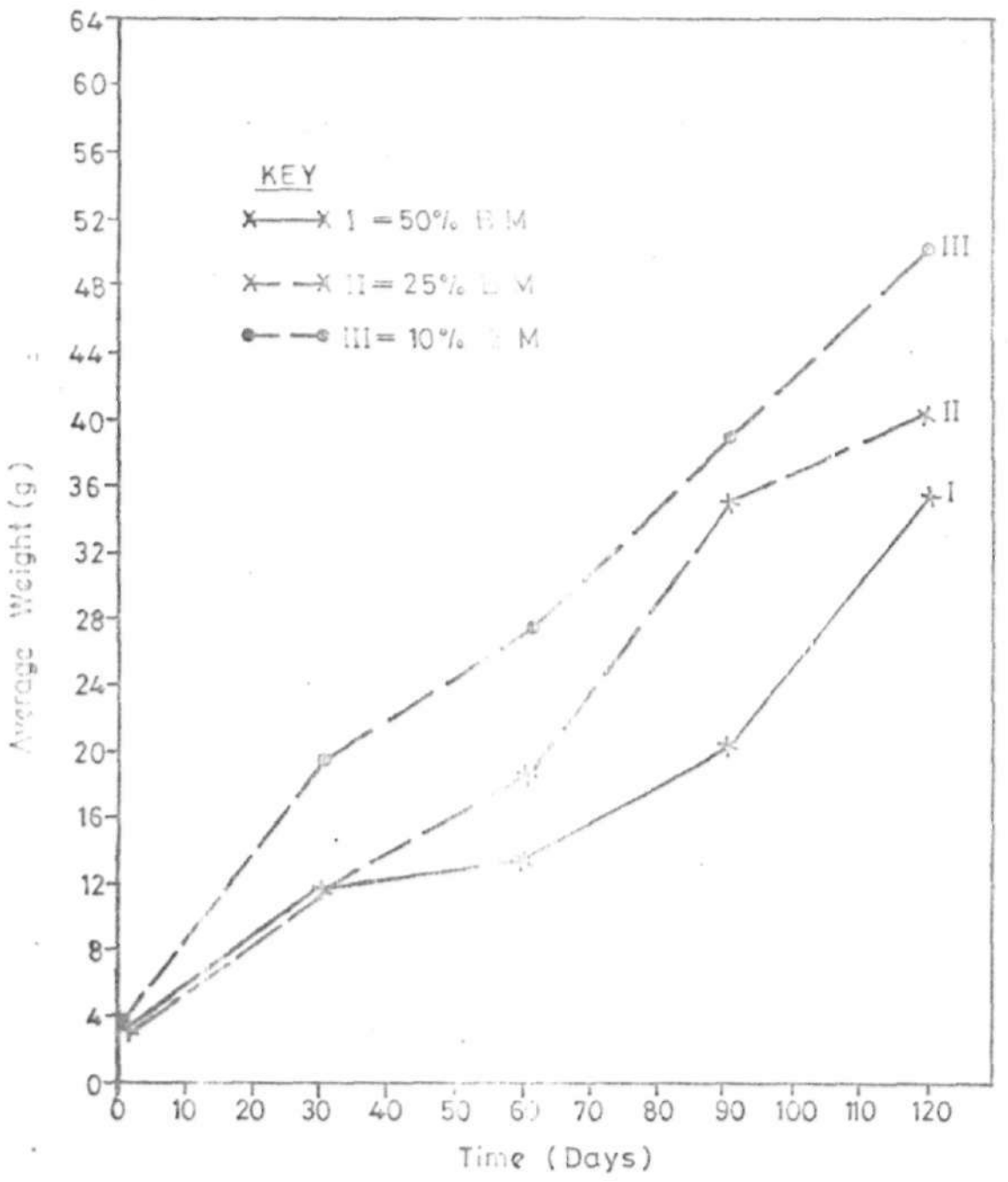


Fig. 5·3 Growth curves of Sarotherodon (Tilapia) niloticus receiving feeding treatments for a period of 120 days.
(B·M=Blood meal

fastest throughout the culture period; treatment II (46.87% crude protein, containing 25% blood meal) overtook treatment I (49.07% crude protein, containing 50% blood meal) till the end of the culture period.

5.3.4.3 Feed Conversion Ratio (FCR)

The best FCR was obtained with treatment II in which 25% blood meal in pelleted feed was fed to Tilapia fingerlings, followed closely by treatment III (10% blood meal) and worst in treatment I (50% blood meal) (Table 5.10). The trend in the FCRs was similar to that of the relative weight gain: treatment II > treatment III > treatment I (Table 5.10). The FCRs were therefore very much truly representative of the efficiency of the different feeds.

5.3.4.4 Total Fish Production

At the end of the 120-day culture period, the highest mean total fish production, 3.910kg/m³ was obtained in treatment III (10% blood meal), followed closely by treatment II (25% blood meal), 3.465kg/m³ and least in treatment I (50% blood meal), 1.993kg/m³ (Table 5.10).

5.3.5 Growth Performance of Tilapia (Oreochromis niloticus) fed with different protein sources in pelleted feeds in floating net-cages

5.3.5.1 Survival rates

The results of some of the physico-chemical parameters of the reservoir during this experiment are given in Table 5.12. The survival rates are shown in Table 5.13.

Table 5.12 Range and mean of some physico-chemical parameters in Kigora III Reservoir during the feeding experiment 5.2.5

Parameters	Range	Mean
Temperature (°C):		
Water	26.0 - 29.0	27.5
Air	29.0 - 31.0	30.0
D.O (pp,)	2.40 - 4.50	4.45
pH	7.0 - 7.4	7.2
Conductivity (µmhos/cm)	200 - 350	275

Table 5.13 Summary of results of Oreochromis niloticus receiving different protein sources in pelleted feeds in floating net-cages for 120 days.

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/day)	FCR	Survival Rate (%)	Total Fish Prodn (kg/m³)
I	21.0	87.0	0.55	1.51	70.0	3.045
Commercial feed	21.0	81.0	0.50	1.42	80.0	3.240
	21.0	84.0a	0.53a	1.47a	75.0a	3.143a
II	21.0	93.0	0.60	1.33	84.0	2.906
Blood meal in	21.0	103.8	0.69	1.31	62.0	3.218
feed	21.0	98.4b	0.65b	1.32a	73.0a	3.062a
III	21.0	64.2	0.36	1.86	72.0	2.311
Fish meal in	20.0	65.6	0.38	1.86	54.0	1.771
feed	20.5	64.9c	0.37c	1.86c	63.0a	2.041a
IV	19.0	113.8	0.79	1.14	76.0	4.324
Groundnut cake	19.0	113.8	0.79	1.09	60.0	3.414
in feed	19.0	113.8d	0.79d	1.12d	68.0a	3.869b

Means in a column with ... significantly different at 5% DMRT.

The highest mean survival rate, 75.0% was recorded in treatment I, followed closely by 73.0% in treatment II; 68.0% in treatment IV and least 63.0% in treatment III.

5.3.5.2 Growth rates

The results of the proximate analysis of the feeds used under this experiment are shown in Table 5.14. Figure 5.4 shows the growth curves of the fish receiving these pelleted feeds in floating net-cages. The mean daily weight gain per fish were 0.79, 0.65, 0.53 and 0.37 g/day in treatments IV, II, I and III respectively (Table 5.13).

5.3.5.3 Feed Conversion Ratio (FCR)

The best feed conversion ratio, 1.12 was obtained in treatment IV, followed by 1.32 in treatment II; then treatment I, 1.47 and least in treatment III, 1.46 (Table 5.13). A critical analysis of the values of mean final weight (per fish), daily weight gain and feed conversion ratio showed that the performance of the feeds in descending order was treatment IV (groundnut) > treatment II (blood meal) > treatment I (soyabean meal) > treatment III (fish meal).

5.3.5.4 Total Fish Production

The trend in the values of the total fish

Table 5.14 Proximate analysis of the four feeds used.

Feed	Crude Protein	P	K	Ca	Mg	Mn	Na	Fe	Ash	Moisture
I Commercial feed (Soyabean meal protein source)	24.52	0.0578	0.080	0.044	0.0316	0	0.0120	0.018	8.0	5.30
II Blood meal in feed	40.28	0.0609	0.280	0.172	0.0134	0	0.0044	0.045	9.9	5.10
III Fish meal in feed	33.27	0.0864	0.052	0.220	0.0160	0	0.0280	0.019	11.8	6.65
IV Groundnut cake in feed	28.02	0.0485	0.040	0.132	0.0172	0	0.0044	0.015	8.9	8.30

NB All figures expressed in percentages except for Mn in ppm.

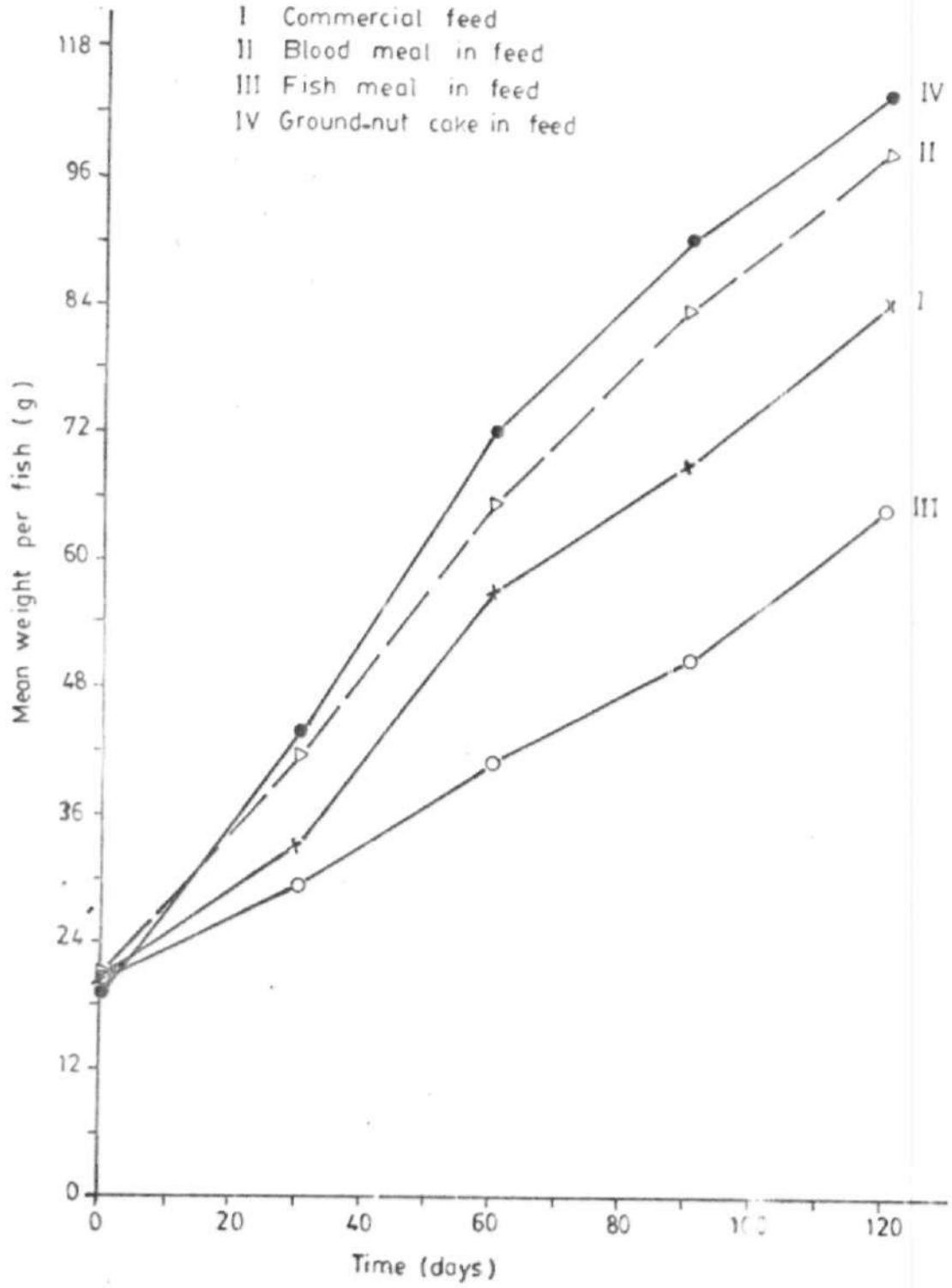


Fig. 5·4 Growth curves of Oreochromis niloticus fed different protein sources in cages for 120 days.

production is very similar to those in mean final weight, daily weight gain and feed conversion ratio that is - treatment IV > treatment II > treatment I > treatment III (Table 5.13). The highest total fish production of 3.869 kg/m³ was obtained in treatment IV (groundnut cake in feed) followed by treatment II, 3.562 kg/m³ blood meal in feed), then treatment I 3.143 kg/m³ (commercial feed) and least in treatment III, 2.041 kg/m³ .(fish meal in feed) (Table 5.13).

5.4 DISCUSSION

5.4.1 Growth Performance of Tilapia fingerlings receiving different feedstuffs in floating hapas

5.4.1.1 Survival Rates

The mortality recorded during the experiment was mainly due to sampling stress while the generally high survival rates were partly attributed to the proper management of the stock (fish) and the physico-chemical parameters (Table 5.4) which were within tolerable range as suggested by Balarin (1979) for tilapia fingerlings production. The pH and water transparency at the site were also observed to be within the desirable range as reported by Swingle (1969) and Boyd (1979), and Huet (1979). However, there were no significant differences ($P > 0.05$) between the mean survival rates of the treatments.

5.4.1.2 Growth Rates

The observations of the sharp and steady increases in the growth rates of the fish under the different treatments could be attributed to the adaptation of the experimental fish to the environment and the different feedstuffs dispensed to them.

Generally, the growth performances of the fish on these feedstuffs could be related to the crude protein, fat and carbohydrate contents of the feedstuffs used. The best growth rate (0.0302g per day) observed in fish fed with corn bran (64.4% carbohydrate) corroborated the observation of Coche (1977) who reported that since O. niloticus is an omnivore with a vegetarian tendency in its natural environment, its ideal diet a priori should contain a relatively high percentage of carbohydrate as an energy source. Coche (1977) observed that O. niloticus could accept very high levels of carbohydrate diet. Rice bran which was analyzed to contain 8.7% crude protein and 3.8% fat had the second highest carbohydrate content (56.9%); brewer's waste (crude protein 18.3%; fat Nil and carbohydrate 45.9%). Even though, the carbohydrate content of brewer's waste was less than that of rice bran, the higher growth rate observed in fish fed brewer's waste (treatment I) could be as a result of the higher protein content (18.3%).

In addition, the stability of the three feedstuffs in water could have contributed to their effective utilization for growth by the experimental fish. Corn bran was observed to float almost indefinitely on the water surface inside the hapas, thus allowing the fry to feed on it and utilize it for growth. However, the mean daily weight gain in treatment III (corn bran) was not significantly different ($P > 0.05$) compared to those of the other three treatments (Table 5.4).

5.4.1.3 Feed Conversion Ratio (FCR)

The trend of the feed conversion ratios was similar to that of the daily growth rates of the fish under the different treatments. The FCR range, 6.53 to 9.12 for the three feedstuffs in this experiment was similar to the FCR values of 5.0 and 8.0 obtained for cereals and rice hull respectively fed to tilapia (FAO, 1976). The mean FCR for rice bran (treatment II) was not significantly different ($P > 0.05$) compared to those of brewer's waste (treatment I) and corn bran (treatment III). The digestibility, stability and nutrient contents of the different feedstuffs could be attributed to the varying FCRs. Corn bran was observed to give the best FCR (6.53), highest mean final weight per fish (1.60g), and highest mean daily weight gain (0.0302g per day). Surprisingly, rice bran reported as the most

important feedstuffs of indigenous origin in Asia especially in the Philippines (FAO, 1983) recorded the worst FCR (9.12) and the least growth rate (0.0167g per day). Perhaps the rice milling method and the rice varieties from which the rice bran (used in this experiment) was obtained from the rice mill at New Bussa, Nigeria is different from that of the Philippines and hence the poor fish growth performance. This observation corroborates that of Wannigama et al. (1985) who reported poor digestibility of diets containing varying levels of rice bran (in cage culture of C. niloticus) and attributed the poor digestibility to the quality of the rice bran. In spite of this, the best growth performances observed in fish fed corn bran was as a result of corn bran containing the highest carbohydrate contents.

5.4.2 Growth Performances of Tilapia fingerlings receiving different combination of industrial and agricultural wastes as supplementary feeds in floating net-hapas

5.4.2.1 Survival Rates

The overall mean survival rate (82.9%) in this experiment was slightly less than that reported under section 5.3.1 (86.9% (Table 5.4). This could be attributed to the smaller size of fry (0.039 - 0.046g) stocked under this experiment compared to size of fry (0.28 to 0.40g) reported under section 5.3.1. In spite of this difference, generally the

survival rates were high in the experiment but the means were not significantly different ($P > 0.05$). The high survival rates were partly attributable to the tolerable range of the physico-chemical parameters (Table 5.5) observed during the experimental period (Balarin, 1979; Boyd, 1979). But, the hapa used for one of the replicates in treatment II suffered loss of some fry through the accidental lowering into water of the top cover of the hapa coupled with the intrusion of one Hemichromis niloticus (a carnivorous Tilapia) into the hapa. This was later detected and removed promptly to avert further predation of the fry stocked.

5.4.2.2 Growth Rates

The growth performances of the fish on these combinations of feedstuffs could be attributed to the nutrients contents of the various feedstuffs used. The highest growth rate recorded by fish in treatment II could be related to the nutrient contents (%) of the feedstuffs: crude protein, carbohydrate and fat were 12.2, 64.4 and 8.6 respectively for corn bran while for rice bran, 8.7, 56.9 and 8.7 respectively (Ezenwa, 1978; Eyo, 1990). The nutrient contents (%) of brewer's wastes were 18.3, crude protein; 45.9 carbohydrate and 0.0, fat (Ezenwa, 1978). Generally, the fish under treatments II and III which involved combinations of feed ingredients (i.e. more

than one feed ingredient) recorded higher growth rates than that under a single feed ingredient, treatment I (corn bran only). Considering the mean final weight (g), there was no significant difference ($P > 0.05$) between treatments II and III (involving more than one feed ingredient) whereas there was significant difference between them (treatments II and III) and treatment I (corn bran only). This observation agrees with the report of IDRC/SEAFDEC (1979) where it was noted that the use of simple diets, either single ingredient or formulated out of locally available sources, was practised in many developing countries. The range of growth rates (g/day), 0.021 to 0.029 in this experiment was comparable to the range, (g/day) 0.0167 to 0.0302 obtained using single feed ingredient in experiment under section 5.3.1, even though the initial sizes of fish used in the latter experiment were about 10 times (in weight) heavier than those under section 5.3.2. There were significant differences in the mean growth rates (g/day) between all the three treatments ($P < 0.05$).

5.4.2.3 Feed Conversion Ratio (FCR)

The range of FCR (4.38 to 5.67) recorded in this experiment was better than the range 6.53 to 9.12 recorded in experiment under section 5.3.1 where single ingredient feedstuffs were fed to Tilapia fry.

The fact that the FCR, 5.67 for corn bran only (treatment I) in this experiment was very close to the FCR, 6.53 also for corn bran only under section 5.3.1 confirmed that the FCRs 4.38 and 4.44 recorded in treatments II and III respectively in this experiment proved the superiority of the combined ingredients feeds used in treatments II and III. However, only the mean of FCR of treatments I and II were significantly different ($P < 0.05$). The FCR range 4.38 to 5.67 obtained in this experiment was better than the range 5.0 to 8.2 reported by FAO (1976) for cereals and rice hulls respectively fed to Tilapia.

Various factors such as digestibility, water stability and nutrients composition of the feedstuffs could be responsible for the differences in the feed conversion observed in this experiment.

5.4.3 Growth Performance of Tilapia fingerlings fed with different agro-industrial wastes (added to constant amount of fish meal) in floating net-cages

5.4.3.1 Survival Rates

The physico-chemical parameters (Table 5.7) observed during the experiment were within tolerable limits for Tilapia growth (Balarin, 1979). The mean air (ambient) and water temperatures were slightly higher (34.3°C and 33.0°C respectively, Table 5.7) because the culture period coincided with the hot, dry season around Lake Kainji area. However, the mean

survival rates of all the treatments were not significantly different ($P > 0.05$).

5.4.3.2 Growth Rates

The trend in the growth performances of fish in this experiment was almost similar to the effect of the single ingredient feedstuffs (i.e. corn bran, rice bran and brewer's wastes) when they were fed singly in the feedstuffs-screening experiment discussed under section 5.3.1. Tilapia growth rates (g/day) were: corn bran, 0.0302 > brewer's wastes, 0.0203 > rice bran, 0.0167. Clearly, corn bran with the highest carbohydrate content, (64.4%) proved to be consistently superior to the other feedstuffs (i.e. rice bran and brewer's waste with carbohydrate contents of 56.0% and 45.9% respectively) (FAO, 1983). Furthermore, the addition of fish meal (ground clupeids, mixture of Pellonula afzeluisi and Sierrathrissa leonensis, 70.0 - 75% crude protein, Eyo, 1990) to the various agro-industrial wastes greatly enhanced their performances towards increased fish growth. Lovell (1981) reported that fish meal was high in calcium, potassium and phosphorus and all the other minerals required by fish and therefore recommended it (fish meal) as a good source of all these nutrients. Akiyama (1988) concluded that the exceptionally well balanced amino acids distribution of fish meal has made it (fish meal) a traditional component of fish feeds. Comparing

the growth rates (g/day) of fish in the experiments under sections 5.3.1, 5.3.2 and 5.3.3, fish under experiment of section 5.3.3 had the highest growth rates (range 0.0865g/day to 0.1175/day) and they attained a size range of 3.68g to 5.01g (Table 5.8) within the same culture period of 42 days as in experiments under sections 5.3.1 and 5.3.2. There were significant differences ($P < 0.05$) between the mean growth rates of fish under all the treatments (Table 5.8).

5.4.3.3 Feed Conversion Ratic (FCR)

The range of these FCR values, 1.13 to 1.29 was best, compared with the range 4.38 to 5.67 obtained using different combinations of the feedstuffs (corn bran, rice bran and brewer's wastes) (Table 5.6) and the range 6.53 to 9.12 obtained in the experiment where the feedstuffs (corn bran, brewer's waste and rice bran) were fed singly to Tilapia fry (Table 5.4).

The low values of FCR under this experiment 5.3.3 further confirmed the efficiency and acceptability of fish meal as a good source of the nutrients required by fish for growth (Lovell, 1981; Akiyama, 1988). Even though the use of fish meal in fish diets appeared limited only by high cost and availability (FAO, 1983). However, there were significant differences ($P < 0.05$) between the means of FCR in all the treatments (Table 5.8).

5.4.4 Growth performances of Tilapia (Oreochromis niloticus) fed different levels of bood meal in pelleted feeds in floating cages

5.4.4.1 Survival rates

These high survival rates were partly attributable to proper management of the stock and

the favourable (within tolerable limits) physico-chemical parameters of the water in the culture site during the culture period (Table 5.9) (Swingle, 1969; Balarin, 1979; Boyd, 1979). There were no significant differences ($P > 0.05$) in the means of survival rates in all the treatments.

5.4.4.2 Growth Rates

The growth rates of the fish under the different treatments in this experiment were inversely related to the percentage of blood meal in the pelleted feeds. This observation is contrary to those made by Otisi and Ufodike (1986) on snake head (Channa obscura) which had an increase in growth rate as the crude protein (12% to 21%) of the diets increased and Jauncey (1981) on Sarotherodon mossambicus in which growth was proportional to the amount of protein in the diet. The implications to fish growth of the different levels of blood meal in the pelleted feeds are appropriately discussed under feed conversion ratio (section (5.4.4.3). However, there were no significant differences ($P > 0.05$) in the means of the relative weight gain (%) between all the three treatments (Table 5.10).

5.4.4.3 Feed Conversion Ratio (FCR)

The FCR values indicated that all three feeds were accepted by the fish and were utilized for growth.

It was very striking that the feed containing the highest amount of blood meal (50%) gave the poorest performance in terms of growth (479.8%) (Table 5.10). This observation corroborated the fact that protein fed in excess of an animal's needs is deaminated and does not contribute to the animal's growth (Cullison, 1979). This is further confirmed by Harper (1967) and Russell-Hunter (1970) that protein at higher levels is in excess of the animal's ability to utilize it anabolically and thus growth decreases presumably as a result of the energetic cost of protein catabolism. The best performance in terms of FCR (1.67), relative weight gain (950.8%) and daily weight gain (6.39g/day) was achieved with the feed containing 10% blood meal (31.34% protein) (Tables 5.10 and 5.11. This confirms the observation that 27% protein feed is suitable for intensive culture of tilapia (ADCP, 1983). Even though, blood meal is extremely high in protein (about 80% protein), it is low in isoleucine, but high in lysine (FAO, 1983); the combination of this rich protein source with corn bran (low in lysine but high in isoleucine) helped to enrich the feedstuffs compounded (Harris, 1980). Recce and Wesley (1975) observed that fresh bovine blood in combination with rumen contents successfully substituted for fish meal in channel catfish diets. This animal protein source (blood meal) is often obtained at little or no cost

from local abattoirs where it is often discarded. Fowler and Banks (1976) noted that blood meal was superior to meat meal in test-diets for salmon. Blood meal, therefore, has a great potential as an inexpensive, effective and readily available protein supplement in aquaculture diets.

5.4.4.4 Total Fish Production

Campbell (1985) observed that fish production was directly related to the quality and amount of feed given to the fish under culture. Cho et al. (1985) noted that a well balanced diet, however, not only resulted in higher fish production but also provided the nutrients necessary to hasten recovery from diseases or aid the fish in overcoming the effects of environmental stress. The best growth performance by the feed containing 10% blood meal was evident by its recording the highest mean final weight (39.1g), highest mean weight gain (35.4g) and the highest mean total fish production (3.910 kg/m^3). This value is comparable to the total fish production of 3.4g/m^3 in 90 days obtained by

Pantastico and Baldia (1979) feeding 20% fish meal in feed at 10% biomass to Sarotherodon mossambicus stocked at 50/m^3 of cage. Philippart et al. (1979) feeding soya pellets (30% protein) at 4.8% biomass

to monosex male Tilapia guineensis stocked at 86/m³ in cages also obtained a similar average monthly fish production of 0.96 kg/m³.

The potentials of blood meal in fish diets for increased fish production have been discussed under section 5.4.4.3.

5.4.5 Growth Performances of Tilapia (Oreochromis niloticus) fed with different protein sources in pelleted feeds in floating net cages

5.4.5.1 Survival rates

The range 63.0% to 75.0% of the survival rates in this experiment was lower than the range 99.0% to 100.0% obtained in the blood meal in feed experiment under section 5.3.4 (Table 5.10). The generally low survival rates was due mainly to sampling stress because mortality was often recorded shortly after some of the sampling exercises. The means of the physico-chemical parameters (Table 5.12) observed in the culture site water were within tolerable range for tilapia culture (Balarin, 1979; Boyd, 1979). There were no significant differences between the mean survival rates of the treatments ($P > 0.05$).

5.4.5.2 Growth Rates

The feed (28.02% CP, Table 5.14) containing groundnut cake as major protein source used in treatment IV gave the highest daily weight gain (0.79g/d). This observation corroborates the report by ADCP (1983) that 27% protein feed was suitable

for intensive culture of tilapia. Even though, it was not possible to analyze every nutrient composition parameters of the experimental feeds in order to obtain the nitrogen free extract (NFE) value, the groundnut cake must have contributed the highest lipid content to the feed used under treatment IV compared with other feeds in the other treatments. The protein-energy ratio of the feed (used in treatment IV) must have been quite ideal and therefore recorded the highest average daily growth rate. This is similar to the observations of Bruton and Allanson (1974), Bruton and Boltt (1975) and Bowen (1979) in the studies of the feeding of Sarotherodon mossambicus. The growth rate, 0.79 kg/day in treatment IV (28.02% protein) compared very well with the growth rate, 0.73g/day obtained by Ishak and Hassanen (1985) feeding 29.0% crude protein (CP) feed to O. niloticus in cages for 120 days in Egypt. The efficiency of groundnut cake as a protein source in fish feed was further confirmed by FAO (1983) which reported that in India it was demonstrated that diets containing 50% groundnut cake as principal protein source could be used as complete feeds for carp.

The growth rate in fish fed with blood meal protein source (feed, 40.28% CP in treatment II, Table 5.14) was the second best, despite the fact that this feed had the highest crude protein content. This observation further confirmed the results obtained

under the experiment in section 5.2.4 where pelleted feeds containing different levels of blood meal were fed to Oreochromis niloticus. It had earlier been discussed that Cullison (1979) noted that protein fed in excess of an animal's needs is deaminated and does not contribute to the animal's growth.

The feed (33.27% CP) in treatment III with fish meal as the major protein source surprisingly recorded the least growth rate of 0.36g/day (Table 5.13), even though, Anonymous (1982) reported that in the Philippines a ration consisting of 77% rice bran and 23% fish meal was found appropriate for tilapia production. A better and perhaps more accurate picture of the performance of the fish meal feed (in treatment III) was presented by Guerrero (1980) in the studies on the feeding of tilapia (O. mossambicus, O. niloticus) different levels of fish meal (25%, 30% and 35%) in floating cages in the Philippines. Guerrero (1980) obtained the highest growth rate of 0.32g/day with the feed containing 25% fish meal and least growth of 0.23g/day with 35% fish meal feed. In this experiment on different protein sources in feeds, the feed containing 25% fish meal (treatment III)

recorded a growth rate of 0.37g/day (Table 5.13) which was comparable to 0.32g/day obtained by Guerrero (1980) using a combination of 25% fish meal and 75% rice bran.

Though the commercial feed used under treatment I was supposed to contain 30% CP minimum (as specified on the production tag by the manufacturer) but proximate analysis showed that it contained 24.52% CP, (Table 5.14). It was therefore, not surprising that this feed (commercial feed) recorded a growth rate of 0.53g/day (Table 5.13) which was less than those of blood meal and groundnut cake separately in feeds under treatments II and IV respectively (Table 5.13). However, the growth rate 0.53g/day obtained using the commercial feed (soyabean as main protein source, treatment I, Table 5.13 and Figure 5.4) was higher than the growth rate, 0.40g/day obtained by Philippart et al. (1979) feeding soya pellets (30% protein) to Tilapia guineensis stocked at 8/m³ in cages.

The mean growth rates of fish in al the treatments were significantly different ($P < 0.05$).

5.4.5.3 Feed Conversion Ratio (FCR)

The FCR value of 1.47 obtained in treatment I (commercial feed) in this experiment was better than the FCR value, 2.2 reported by Philippart et al.(1979) feeding commercial pellets (46% protein) to O. niloticus at 100/m³ in cages. In treatment II (25% blood meal as protein source) the FCR value of 1.32 recorded was comparable to the FCR value of 1.36 reported under

experiment in sections 5.2.4 and 5.3.4 (Table 5.10) also involving 25% blood meal in pelleted feed. The FCR, 1.32 for treatment II under section 5.2.5 was better than FCR, 1.36 for treatment II under section 5.2.4 and could be attributed to better utilization of the pelleted feed (under section 5.2.5) because feed loss/wastage was reduced to the barest minimum by the hapa-netting sewn to the under side of the bottom wall of the net-cages used in this experiment (section 5.2.5). The pelleted feeds dispensed settled on the fine-meshed hapa netting from which the fish fed on the sinking feed. This observation was corroborated by Guerrero (1980) who reported that the relatively poor conversion ratios of the diets (made from different levels of fish meal) by O. niloticus in cages could be partly explained by feed wastage. It was therefore not surpising that 25% fish meal in pelleted feed in treatment III gave a better feed conversion ratio of 1.86 than the FCR value of 3.1 obtained by Guerrero (1980) feeding 25% fish meal and 75% rice bran as a mash to O. niloticus in cages.

The feed conversion ratio, 1.12 obtained using 25% groundnut cake in feed (28.02% crude protein) in this experiment was better than the FCR value of 2.23 reported by Campbell (1985) feeding 28.0% protein feed (made up of 11% groundnut cake, 20% cotton seed cake and 9% fish meal (tuna waste) as major protein

sources) under large scale cage farming of Sarotherodon niloticus in the Ivory Coast. The FCR, 1.12 (in treatment IV) was also superior to the FCR value, 2.90 obtained by Ishak and Hassanen (1985) in the 120-day cage rearing of O. niloticus fed with 29.0% protein feed made up of 8% fish meal, 5% meat meal and 26% cotton seed meal as major protein sources.

Generally, the feed conversion ratios (range 1.12 to 1.86) (Table 5.13) obtained under this experiment were better than the FCRs (range 1.36 to 2.17) reported under the experiment in sections 5.2.4 and 5.3.4 (Table 5.10) using different levels of blood meal in pelleted feeds.

All the means of the FCR of all the treatments in this experiment were significantly different ($P < 0.05$).

5.4.5.4 Total Fish Production

Campbell (1985) reporting on the large scale commercial cage farming of Sarotherodon niloticus concluded that fish production was directly related to the amount and quality of feed given. This was corroborated by the direct relationship observed between the FCR values and total fish production since FCR can serve to some extent, as an indicator of the efficiency or nutritional value of the feeds (Hepher and Pruginin, 1982). Treatment IV which had

the best FCR (1.12) recorded the highest total fish production (3.869 kg/m³) while treatment III with the least FCR (1.86) had the least total fish production (2.041 kg/m³) (Table 5.9). The range (2.041 to 3.869 kg/m³) of mean fish production obtained in this experiment lasting only 120 days (but ranged between 9.854 and 15.630 kg/m³ in 365 days) was better than the range, 0.9 to 1.4 kg/m³ in 56 days (i.e. 5.868 to 9.128 kg/m³ in 365 days) obtained by Guerrero (1980) feeding varying levels of fish meal in feed to Oreochromis niloticus in floating cages in the Philippines.

The mean total fish production in treatment IV (groundnut cake in feed) was significantly different from the mean total fish production in all the remaining three treatments ($P < 0.05$).

5.5 CONCLUSION AND RECOMMENDATION

Weatherly and Cogger (1977) had identified cost of protein as a principal obstacle in culture of fish. The series of feeding experiments carried out under

this chapter were aimed at a systematic evaluation of various agricultural and industrial by-products singly and in combination with some other readily available feedstuffs in order to obtain practical diets for the nursery and the grow-out phases of Tilapia (Oreochromis niloticus) cage culture. The data for the conclusions as summarized in Appendix 2.

Under the nursery-related experiments, it could be concluded that:

(i) Corn bran gave the best FCR (6.53), highest average final weight (1.60g/fish) and the fastest growth rate (0.0302g/d/fish) (Appendix 2).

(ii) The combination of corn bran and brewer's waste (in ratio 1:1) gave the best FCR (4.[illegible]), highest average final weight (1.[illegible]g/fish) and the fastest growth rate (0.[illegible]29g/day/fish) and the fastest growth rate (0.029g/day/fish) (Appendix 2).

(iii) The feed containing corn bran with constant amount of fish meal and premix gave the best FCR (1.13), highest average final

(5.01g/fish) and the fastest growth rate (0.1175g/day/fish) (Appendix 2).

Whereas, under the grow-out phase experiments, it could be concluded that:

(i) The feed containing 10% blood meal was the most efficient in terms of average final weight (39.1g/fish), growth rate (0.39g/day/fish) and total fish production (3.910 kg/m^3).

(ii) The feed containing groundnut cake as a major protein source was the most efficient in terms of average final weight (113.8g/fish), growth rate (0.79g/day/fish), FCR (1.12) and total fish production (3.869kg/m^3).

Considering the observations made above, it is recommended that:

(i) for the nursery production of Tilapia (O. niloticus) fingerlings, the feed (in powdered form) containing 25% fish meal, 74% corn bran and 1% premix is efficient for fast growth of fry to fingerlings in net-hapas.

(ii) for the grow-out phase in production of table size Tilapia (O. niloticus), the feed (in pellet form) containing 25% groundnut cake, 74% layer's concentrate/ corn bran (in ratio 1:3) and 1% premix is ideal for fast growth of fingerlings to table-size Tilapia in net-cages.

Since there were large annual crops of cotton in Egypt, cotton seed meal is the principla protein source for feeds in that country (FAO, 1983). Like cotton seed in Egypt, groundnut cake can become a principal protein source for feeds in Nigeria if the "groundnut pyramids" of the norther states of Nigeria can be revitalized through an agrarian revolution. FAO (1983) reported that in Nigeria from an annual groundnut crop of 620,000 tons, more than 380,000 tons of groundnut cake could be made available if all the seeds were crushed for oil. Abundant production of groundnut cake would invariably lead to a reliable solution to the incessant problem of inadequacy of efficient fish feed for fish production.

Since Nigeria has large reserves of petroleum or natural gas, it is also recommended that the possibility of large scale production of single cell protein from these natural resources should be exploited.

CHAPTER 6

6.0 STOCKING DENSITIES EXPERIMENTS USING TILAPIA (Oreochromis niloticus) WITH OR WITHOUT SUPPLEMENTARY FEEDING IN FLOATING CAGES

6.1 INTRODUCTION

Stocking density is usually represented as the number or weight of fish stocked per unit area or volume of the culture medium/space (i.e. in No or kg per m^2 or m^3). Stocking density had been reported to affect survival, growth and production of fish (Albrecht and Gollub, 1971; Steffens, 1971; Konikoff and Lewis, 1974; Wojno, 1976; Beveridge, 1987). The rapid spread of disease among caged fish could be attributed to high stocking densities (Beveridge, 1987). In yellow tail cage culture, mortalities as high as 50 could occur because the fry could be cannibalistic particularly at high stocking densities (Honma, 1980). Beveridge (1987) reported that the stocking density depended on the size of the fish and the prevailing environmental conditions. Fujiya (1979) noted that in yellow tail cage farming, the stocking density increases from a minimum of 0.9kg/m^3 when the fish were first stocked in the grow-out cages at an average weight of 10g per fish, to a maximum of 11kg/m^3 when the fish reached 500g. However, Kafuku and Ikenoue (1983) opined that under ideal conditions, stocking densities (yellow tail) of up to 20kg/m^3 could be achieved. Taniguchi (1983) observed that preventive

measures against mortalities caused by Streptococcus in yellow tail culture included low stocking densities and maintenance of good water quality among others. Escover and Claveria (1985) observed that in cage culture of Tilapia. stocking densities ranged from 5 to 50 fingerlings per m³ depending on site, cage size, feeding practices and desired size at harvest. Bautista (1984) opined that stocking densities could also change with season and from year to year. Trzebiatowski et al. (1981) reported that it was evident that the rainbow trout stocking density might differ depending on environmental conditions, water flow speed and culture system as well as on market requirements.

Most of the above observations on the effect of stocking density on fish production in cages have not been studied in Nigeria. The main objective of this chapter is to determine the effect of stocking density on the survival, growth and production of fish (Tilapia) in the floating cage culture system.

6.2 MATERIALS AND METHODS

For the purpose of comparison the following three experiments were carried out. The first experiment (6.2.1) on stocking densities (25-100/m³) at Kigera III Reservoir was aimed at determining the effect of rearing the caged fish compared with experiment 6.2.2 involving stocking density (200/m³

maximum) using a supplementary feed with slightly higher protein content for usual 150-day culture period. The third experiment (6.2.3) however, was to exploit the natural productivity of the Lake (at Intermediate Basin) without supplementary feeding at similar stocking densities as in experiment 6.2.1.

6.2.1 The Effect of Stocking Density (25-100/m³) on Tilapia Production in Floating Net-cages in Kigera III Reservoir

The experiment consisted of four treatments:

i) 25 fish/m³

ii) 50 fish/m³

iii) 75 fish/m³

iv) 100 fish/m³

Each treatment was replicated in three cages (1.0 x 1.0 x 1.5m net-cage size) in a completely randomized design. Tilapia fingerlings, average size 4.6 - 6.7g were randomly stocked in the net-cages early in the morning. The fish were fed with a 17.3% crude protein pelleted feed at 6% of their biomass per day. The fish daily ration was adjusted monthly by sampling 20% of the fish for body weight changes. The fish were harvested after 365 days culture period (16 March 1986 to 15 March 1987). Some physico-chemical parameters of the water at the culture site were also monitored as described under section 3.8.

6.2.2 The Effect of Stocking Density (25-200/m³) on Tilapia Production in Floating Net-Cages in Kigera III Reservoir

The treatments I, II, III and IV corresponding to 25, 50, 100 and 200 fish/m³ respectively were assigned to net-cages (1.0 x 1.0 x 1.5m size) using completely randomized design. Oreochromis niloticus fingerlings (average weight, 5.5 - 7.0g) were stocked according to the treatments into the cages. Each treatment was replicated twice. The fish in all the treatments were fed with 18.9% crude protein pelleted feed at 6% of their biomass twice daily (08.00 and 18.00 hrs). The daily ration of the fish was adjusted monthly after sampling for growth. The fish were harvested after 150 days culture period (16 April - 12 September 1987).

6.2.3 The Effect of Stocking Density (25 - 100/m³) on Tilapia Production in Net-Cages at the Intermediate Basin, NEPA Kainji Dam Site

The site for this experiment had earlier been described under section 3.2.1 (Figure 3.1). Four treatments: I, 25 fish/m³; II, 50 fish/m³; III, 75 fish/m³ and IV, 100 fish/m³ were used in this experiment with no supplementary feeding. The

fish were made to subsist mainly on the natural food in the culture site. Tilapia fingerlings (average size, 15.0 - 19.0g) were stocked into net-cages (1.0 x 1.0 x 1.5m size, 12.7mm mesh) early morning. Each treatment was replicated twice. The fish were sampled monthly for growth. The fish were harvested after 150 days culture period (11 March - 7 August 1988).

6.3 RESULTS

6.3.1 Performances of Tilapia Stocked at Densities of 25 - 100 fish/m² in Cages in Kigera III Reservoir

6.3.1.1 Survival

The survival rates recorded in this experiment were high: treatment I, 93.9%; treatment III, 90.2%; treatment II, 87.0% and least in treatment IV, 77.5% (Table 6.1). The average survival rate for all the four treatments was 87.7%. Table 6.2 shows the results of some physico-chemical parameters of the reservoir during the experiment.

6.3.1.2 Growth

The growth rate (g/fish/day) was highest in treatment I (0.34), followed by treatment II (0.22), then treatment III (0.19) and least in treatment IV (0.16) (Table 6.1). It was observed that the growth rate of the fish generally decreased with the increase in stocking density.

Table 6.1: Results for Tilapia sp stocked in Cages at Different Densities for 365 Days Culture Period at Kigera III Reservoir, New Bussa

Treatment	Average Wt. (g) Initial	Final	Average Daily Wt. gain (g/d)	Survival (%)	Production (kg/m³)
I	4.9	100.0	0.26	95.0	2.376
25/m³	5.6	150.8	0.40	94.4	3.465
	5.4	133.3	0.35	94.3	3.143
	5.3	127.8a	0.34a	93.9a	2.994b
II	6.8	97.2	0.25	91.2	4.432
50/m³	6.2	64.7	0.16	88.9	2.847
	7.1	100.9	0.25	87.8	4.390
	6.7	87.3b	0.22	89.0	3.889ab
III	4.8	72.5	0.19	90.0	4.894
75/m³	5.4	74.0	0.19	89.5	4.967
	5.4	79.2	0.20	91.1	5.411
	5.2	75.2b	0.19b	90.2bc	5.091a
Iv	4.8	58.7	0.15	75.8	4.449
100/m³	4.5	71.7	0.18	80.2	5.750
	4.5	61.4	0.16	76.5	4.697
	4.6	63.9b	0.16b	77.5d	4.965a

Means in a column with the same superscript are not significantly different at 5% DMRT

Table 6.2: Range and Mean of Physico Chemical Parameters of Kigera III Reservoir During the Experimental Period

Parameter	Range	Mean
Temperature (°C):		
Air	26.0-40.0	30.5
Water	23.0-38.0	30.5
pH	7.1- 7.5	7.3
Dissolved Oxygen (mg/l)	4.0- 6.8	5.4
Transparency (m)	0.39-0.40	0.40
Conductivity (µmhos/cm)	250-320	285

6.3.1.3 Production

The total fish production (kg/m³) was highest in Treatment III(5.091), followed by Treatment IV(4.965 then Treatment II (3.889) and least in Treatment I (2.994). Unlike in the case of growth rates (and average final weight per fish), the total fish production generally was directly related to the stocking densities - the production increasing with increasing stocking density (Table 6.1) except for Treatment III (75 fish/m³).

6.3.2 Performances of Tilapia stocked at Densities of 25 - 200 fish/m³ in Kigera III Reservoir

6.3.2.1 Survival

The survival rates recorded in the experiment were generally very high: Treatment I, 100%; Treatment II, 99.5%; Treatment III,99.0% and least in Treatment IV, 94.5% (Table 6.3). The survival rates were observed to decrease gradually as the stocking density increased (inverse relationship).

6.3.2.2 Growth Rates

The mean daily weight gain of the fish under the different treatments is shown in Table 6.3. The mean growth rates (g per fish per day) for treatments I, II, III and IV were 0.48, 0.43, 0.36 and 0.21 respectively.

Table 6.3: Results for Tilapia sp. Production at Different Stocking Densities in Floating Cages at Kigera III Reservoir for 150 Days Culture Period

Treatment	Average Wt. (g)		Average Daily Wt. gain (g/d)	Survival (%)	Total Production (kg/m³)
	Initial	Final			
I	[illegible]	78.9	[illegible]	100.0	1.973
25/m³	5.6	79.1	0.49	100.0	1.978
	7.0	79.0[a]	0.48[a]	100.0[a]	1.976[a]
II	6.0	63.0	0.38	100.0	3.150
50/m³	5.0	75.5	0.47	99.0	3.737
	5.5	[illegible][ad]	0.43[ad]	99.5[a]	3.444[a]
III	7.2	58.2	0.34	99.0	5.762
100/m³	6.1	61.6	0.37	99.0	6.098
	6.7	59.9[bd]	0.36[bd]	99.0[a]	5.930[b]
IV	5.5	40.0	0.23	96.0	7.680
200/m³	5.9	34.4	0.19	93.0	6.398
	5.7	37.2[c]	0.21[c]	94.5[b]	7.039[c]

Means in a column with the same superscript are not significantly different at 5% DMRT

6.3.2.3 Production

The total fish production values (kg/m³) in the experiment were 1.976, 3.444, 5.930 and 7.039 for Treatments I, II, III and IV respectively (Table 6.3). The production was observed to increase with increase in the stocking density.

6.3.3 Performances of Tilapia stocked at Densities of 25 - 100 Fish/m³ in Cages (without feeding) at Intermediate Basin, NEPA Kainji Dam Site

6.3.3.1 Survival

The survival rates of O. niloticus stocked at different densities without supplementary feeding are shown in Table 6.4. The survival rates were generally low, ranging from 18.0% for Treatment I to 47.0% for Treatment III. Table 6.5 shows the results of some physico-chemical parameters of the Basin during the experiment.

6.3.3.2 Growth Rates

Table 6.4 shows the growth rates of the fish under the different stocking densities at Intermediate Basin of NEPA Kainji Dam Site. The growth rates were 0.27g/fish/day in treatment II; 0.31g/fish/day in both treatments III and IV; and highest in treatment I (0.39/fish/day).

Table 6.4: Results for Tilapia Production at Different Stocking Densities (without supplementary feeding) in Floating Net-Cages at Intermediate Basin, NEPA Kainji Dam Site for 150 Days

Treatment	Average Weight (g)		Average Daily Wt Gain (g/d)	Survival (%)	Total Production (kg/m³)
	Initial	Final			
I 25/m³	18.0 16.0 17.0	61.5 89.5 75.5[a]	0.29 0.49 0.39[a]	8.0 28.0 18.0[a]	0.123 0.627 0.375[a]
II 50/m³	19.0 16.0 17.5	74.5 41.5 58.0[a]	0.37 0.17 0.27[a]	44.0 16.0 30.0[a]	1.639 0.332 0.986[a]
III 75/m³	17.0 17.0 17.0	65.0 62.0 63.5[a]	0.32 0.30 0.31[a]	47.0 47.0 47.0[a]	2.291 2.186 2.239[a]
IV 100/m³	15.0 15.0 15.0	54.0 69.0 61.5[a]	0.26 0.36 0.31[a]	31.0 62.0 46.5[a]	1.674 4.278 2.976[a]

Means in a column with the same superscript are not significantly different at 5% DMRT

Table 6.5: Ranges and Means of Physico-chemical Parameters of Intermediate Basin, NEPA Kainji Dam Site During the Experimental Period

Parameter	Ranges	Means
Water Temperature (°C)	28.6-29.8	29.0
pH	7.8- 8.2	8.0
Dissolved Oxygen (mg/l)	6.4- 8.6	7.5
Transparency (m)	0.43-0.77	0.6
Conductivity (µmhos/cm)	65-82	73

6.3.3.3 Production

The total fish production (kg/m³) during the 150-day culture period were 0.375, 0.986, 2.239 and 2.976 for Treatments I, II, III and IV respectively (Table 6.4). In spite of the low survival rates as explained earlier, the total fish production was observed to have a direct relationship with the stocking densities, i.e. the total fish production increased as the stocking densities increased.

6.4 DISCUSSION

6.4.1 Performances of Tilapia Stocked at Densities of 25 - 100 Fish/m³ in Cages in Kigira III Reservoir

6.4.1.1 Survival

The average survival rate in this experiment was higher than the average survival rates of 62.5% and 74.2% recorded for O. niloticus stocked at densities (50 - 100/m³) in running water and standing water respectively by Ishak (1987).

Considering the duration of culture (365 days), O. niloticus at the varying densities stocked were able to adapt to the culture environment and survive in the cages. There were significant differences between the mean survival rates in the treatments ($P < 0.05$) (Table 6.1).

6.4.1.2 Growth Rates

It is often stated that the degree to which fish are crowded together will affect growth (Weatherly, 1972). A similar relationship (inverse relationship between stocking density and growth rate) has been reported by Albrecht and Gollub (1971) and Wojno (1976). Wedemeyer (1976) opined that at high fish stocking densities, the freedom of movement and feeding are hampered, thus the availability of food, even when the latter is offered in excess, becomes a limiting factor.

At the stocking density of 50 fish/m^3, the fish growth rate, 0.34g/fish/day was higher than the growth rate, 0.17g/fish/day in running water at a similar stocking density (50/m^3) reported by Ishak (1987).

The growth rate in Treatment I was observed to be significantly different from those of the other treatments ($P < 0.05$) (Table 6.1).

6.4.1.3 Production

The fish production in all the treatments were generally lower than 0.9 to 1.4kg/m^3 in 56 days (i.e. 5.868 to 9.128 kg/m^3 in 365 days) in cages obtained by Guerrero (1980) using O. niloticus (100 fish/m^3) but feeding 25 to 35% fish meal in pelleted feed. On the other hand, with no supplementary feeding, Ishak (1987) reported a total production of 0.782kg/m^3 in 150 days (i.e. 1.902kg/m^3 in 365 days) stocking O. niloticus at 50/m^3 in running water. He concluded that the low fertility of the water among other causes

was responsible for the relatively low production and that the natural fertility of a given water body was an important factor to be considered for increased production of O. niloticus. This is further supported by Warren (1971) who opined that growth (also a factor related to production) as a response to the integrated activities of an organism as a whole is a sensitive parameter of the suitability of the environment. The generally slow growth (hence total production) of the fish in this experiment may be attributed to low productivity of Kigera III Reservoir. Plankton production has already been reported to be relatively low in the reservoir (Abohweyere, 1990). However, there were significant differences between the means of total fish production under the different treatments $P < 0.05$).

6.4.2 Performances of Tilapia Stocked at Densities of 25 - 200 Fish/m³ in Cages in Kigera III Reservoir

6.4.2.1 Survival

The range of survival rates (94.5% to 100.0%) under the stocking densities 25 - 200/m³ was higher than the range 77.5% to 93.9% recorded when O. niloticus was stocked at between 25 and 100 fish/m³ in section 6.3.1. This observation corroborates that of Lewis (1969) who reported that many fishes would fight when confined in moderate densities (25 to 75 fish per m³), but these same fish would thrive at higher densities (200 to 300 fish per m³).

In addition, the high survival rates could be attributable to the favourable physico-chemical parameters of the culture medium (Table 6.2). The ranges of the physico-chemical parameters recorded during the period of the experiment were within the tolerable ranges for Tilapia (Swingle, 1975; Balarin, 1979; Guerrero, 1982). However, the mean survival rate recorded under Treatment 2) (200 fish/m^3) was significantly different ($P < 0.05$) from those of all the other three Treatments (Table 6.3).

6.4.2.2 Growth Rates

The observation showed an inverse relationship between the stocking densities and the growth rates, i.e. as the stocking densities increased, the growth rates decreased. This is similar to the observation of Trzebiatowski et al. (1981) who reported that for rainbow trout (Salmo gairdneri) individual growth rate and natural losses were inversely proportional to stocking densities.

The range of the mean growth rates (0.21 to 0.48g/fish/day) in this experiment (Table 6.3) was higher than the range, 0.16 to 0.34 g/fish/day recorded at the stocking densities range of 25 to 100 fish per m^3 (Table 6.1). In spite of the fact that the initial total fish biomass per treatment average 565.0g/m^3) for the stocking densities (25 - 200 fish/m^3)(Table 6.3) was

higher than the initial total fish biomass per treatment (average 329.4g/m³) for 25 - 100/m³ (Table 6.1), the mean growth rates for the Treatments (25 to 200 fish/m³) were still higher than for the Treatments (25 to 100 fish/m³).

The fact that the fish stocked at higher densities (25 to 200/m³) and higher biomass (175.0 to 1140.0g/m³) still grew faster than those stocked at lower densities (25 to 100/m³) proved that the culture site was still capable of sustaining the growth of the fish; i.e. the carrying capacity of the medium had not been exceeded. Hickling (1971) noted that the carrying capacity also referred to as maximum standing crop would vary with the water supply. He further stressed that fish could be very densely stocked in cages because they are in flowing water and so run no risk of asphyxiation. This is further confirmed by Bardach et al. (1972) who noted that even though fish in cages are physically restrained in a very small area, the amount of clean, oxygenated water available is theoretically unlimited. Bardach et al. (1972) therefore elucidated that in Japan while Chinese carp fry were stocked at 1,400 to 1,800/m² in pond the fry were stocked at 15,000 to 62,000/m² in net-cages. Coche (1982) therefore concluded that the maximum carrying capacity of a cage (in kg/m³) is mainly determined by the dissolved oxygen concentration throughout the cage.

Since the size range of fingerlings (5.5 to 7.0g) stocked in this experiment (Table 6.2) was similar to the size range (4.6 to 6.7g) stocked in the experiment under section 6.3.1, the marked difference in the growth rates of fish in the comparable stocking densities (25, 50 and 100 fish/m²) could be attributed to the food (natural and artificial) available to the fish in the environment. The quality of the pelleted feed (18.9% crude protein, made up of 10% blood meal, 89% corn bran and 1% premix) fed to fish in this experiment could have contributed to the faster growth rates of the fish compared to the 17.3% crude protein feed (consisting of 40% brewer's waste, 43.5% corn bran, 14.5% layers concentrate and 2.0% starch as binder) fed to fish in the experiment under section 6.3.1.

However, the mean growth rate of fish under Treatment I was significantly different ($P < 0.05$) from the mean growth rates under Treatments II, III and IV.

6.4.2.3 Production

The observation in this experiment is similar to that of Trzebiatowski et al. (1981) on rainbow trout. The range of total fish production in this 150-day experiment (1.976 to 7.039kg/m³; average, 4.597kg/m³) is better than the range (2.994 to 5.091 kg/m²; average, 4.235kg/m³) recorded in the 365-day experiment under section6.3.1. Generally, the total fish production in this experiment were higher than the range 1.6 to 2.4

kg/m³ obtained by Garcia (1979) and Guerrero (1979) stocking S. mossambicus fingerlings (5-10g) average weight at 16 fish/m³ for a 6-month culture period. Considering the treatment with 100 fish/m³, the total fish production is quite low compared to the total fish production values of between 10.5 and 15.8 kg/m³ obtained by McLarney (1978) and Popma (1978) stocking Tilapia rendalli (average size 24.8g) at 100 fish/m³ for between 3 months + to about 7 months. In the Philippines, Guerrero (1979) reported a total fish production of 25.0kg/m³ stocking S. niloticus (average size 20g) at 250 fish per m³ and fed 24.2% dry weight of protein for 2 months. This production is definitely higher than the value 7.039kg/m³ obtained under Treatment IV (200 fish/m³) in this experimen . In Ivory Coast, Campbell (1978) obtained a total fish production range of 13.3 to 49.9 kg/m³ feeding 20% protein feed to O. niloticus (average 84% males, average size, 26g) stocked at between 71 to 185 fish/m³ in Lake Kossou for between 108 and 131 days culture period. This total fish production range is definitely higher than the range 1.9?5 and 7.039kg/m³ obtained in this experiment even though under a mixed sex culture.

Since growth is a factor directly related to production, the growth rates of 0.37 to 0.79g/fish/day obtained from feeding pelleted feed of different protein sources (Table 5.13) to O. niloticus stocked at 50 fish/m³ evidently proved that a well balanced feed will result

in faster growth rate and hence higher fish production even at higher fish stocking densities. For example, Suwanasart (1972) reported growth rates of 0.72 to 1.72g/day and total fish production of 54.8 to 83.3kg/m^3 feeding 40% protein feed (floating or sinking) to S. aureus (2.5g average size) stocked at 500 fish per m^3 in a 3-month culture period. Armbrester (1972) similarly fed 40% protein feed to S. aureus (average size, 2.9g) at 600 fish/m^3 and obtained a growth rate of between 0.56 to 0.76 g/day and a total fish production of 56.4 kg/m^3 in 2.5 months but in the presence of moderate plankton blooms. The mean weight per fish at harvest obtained by Armbrester (1972) ranged between 39 and 73g and was comparable to the values 37.2 to 79.1g recorded under this experiment. It was interesting to note that Pagan (1973) feeding 40% protein to S. aureus (average size, 13g) stocked at 857 fish/m^3 obtained a growth rate of 1.39g/fish/day; average final weight per fish at harvest, 174g and a total fish production of 149kg/m^3 in a 5.2-month culture period. This observation further confirmed the role of artificial feed (especially complete feed) in intensive, high density cage fish culture (Campbell, 1985).

However, there were significant differences ($P < 0.05$) between the mean total fish production values under the different treatments.

6.4.3 Performances of Tilapia Stocked at Densities of 25 - 100 Fish/m^3 in Cages (without feeding) at Intermediate Basin, NEPA Kainji Dam Site

6.4.3.1 Survival

The survival rates were generally low, not because the fish could not survive but they were lost as a result of leakage in most of the cages which were fairly old. The fairly old net cages could have been gnawed at by the herbivorous fish (including the stocked Tilapia which were not supplementarily fed). Some of the stocked fish therefore escaped through the holes made in the cage walls especially at the bottom corners. Since the fish loss was first observed after 2 months culture period and also when algal growth had covered the twines of the nylon net-cages, it was likely that herbivorous fish (including the stocked Tilapia) had been attracted to the algae covering the twine and gnawed at both the twine and the algae. A similar problem (gnawing at net-cage) had been reported in Israel by Ben Yami (1974) in the cage-raising of a herbivorous rabbit fish (Siganus rivulatus). He noted that as a result many fish escaped. The physico-chemical parameters (Table 6.5) recorded during the experimental period were within favourable limits as recommended for Tilapia by Swingle (1961), Balarin (1979) and Guerrero (1982). In fact, Adeniji and Ita (1976) having carried out a limnology and fisheries investigation of the Intermediate Basin for recreational fishing concluded that generally

the limnological characteristics of the basin (i.e. water temperature, D.O, Water Transparency and Plankton) were favourable to good growth and survival of fish. There were no significant differences ($P > 0.05$) between the mean survival rates under the different treatments.

6.4.3.2 Growth Rates

Even though the stocked fish subsisted solely on natural food in the water medium, the range of growth rates (0.27 to 0.39g/fish/day) was better than the range (0.16 to 0.34g/fish/day) recorded under similar stocking densities of O. niloticus fed with supplementary feeds in net-cages at Kigera III Reservoir (Table 6.5). Since the fish in all the treatments grew well it could be concluded that the natural productivity of the water (at the Intermediate Basin) was adequate to sustain the fish in the cages. Adeniji and Ita (1976) had earlier observed that the species of plankton in the basin were similar to those present in the lake (Lake Kainji). Good growth of O. niloticus had earlier been reported in a mixed species cage culture of fish (at Shagunu Bay also located on Lake Kainji) with little or no supplementary feeding (Table 4.3). Coche (1982) reported an average growth rate of 0.89g/fish/day for S. mossambicus (average size 6g) stocked at 25 to 75 fish/m^3 without supplementary feeding at Laguna de Bay (a hypereutrophic Lake) in the Philippines. Extensive commercial Tilapia farming utilizing the natural

productivity of Laguna Lake has been reported by Santiago (1982); Escover and Claveria (1985); Lazaga and Roa (1985). Although when first exploited, Laguna de Bay was sufficiently productive to support high densities of fast growing fish without recource to the use of feeds (PCARRD, 1981; Coche, 1982). However, Beveridge (1984) reported that this Lake (Laguna) had been rapidly over-exploited as a result of over-crowding of fish cages. In Singapore, Yang (1982) reported the successful use of cages of big head carp at several reservoirs to control excessive plankton blooms in municipal water supplies.

Frequent occurrences of algal blooms have been reported in Lake Kainji especially during the month of October (Adeniji, 1973). Extensive Tilapia cage culture as observed in the Intermediate Basin can in addition benefit from this period of high phytoplankton densities in Lake Kainji.

Furthermore, the average weight of fish (average 16.6g) stocked under this experiment (Table 6.4) seem to be advantageous in the comparable good growth rate recorded considering the average size of 5.5g stocked under similar stocking densities (25-100/m^3) in Kigera III Reservoir (Table 6.1). This corroborates the report of Ishak (1985) who observed that the cage culture of common carp showed that the size of fish at stocking was a limiting factor for production/m^3. He noted that when common carp were stocked at an initial

average size of 2/g/fish, maximum production rate of 20kg/m³ was obtained in a 4m³ cage at a stocking density of 160 fish/m³ while when the stocking size was 95g/fish, maximum production rate was 32.5kg/m³ at a stocking density of 60 fish/m³.

6.4.3.3 Production

Since the average final (at harvest) weight/fish has a directly relationship with the total fish production, in 365 days the estimated average final weight per fish in the Intermediate Basin would have been 151.2g compared to 88.6g recorded under similar stocking densities (but with supplementary feeding) in Kigera III Reservoir. But for the leakage in the cages which resulted in serious fish loss (hence low survival rates), the total fish production at the Intermediate Basin under the extensive culture could have been quite high (an average of 14.148 kg/m³ per year assuming 90% survival and 151.2g/fish). Coche (1982) noted that the maximum carrying capacity (MCC) of a cage (in kg/m³) is mainly determined by the dissolved oxygen throughout the cage. He noted that MCC varies with the mesh size and cage size. The water in the cages during the experimental period was observed to be well oxygenated (average D.O., 7.5mg.l, Table 6.5). Considering the mesh size and cage size, Campbell (1978) has defined the MCC (in kg/m³) for O. niloticus reared in well-oxygenated water with good circulation (at least 2 cm/sec) as follows; with plastic netting 2mm mesh, 90 for 1 m³, 70 for 6 m³ and 40 for 20 m³;

with nylon fibre netting of 14 mm mesh, 40 for 20m³ Therefore as cage size increases, MCC decreases. Since a nylon fibre netting of 12.7 mm mesh and cages size 1.0 x 1.0 x 1.5m were used in the Intermediate Basin experiment, based on the definition of MCC by Campbell (1978), the MCC of the cages could be higher than 40 kg/m³.

6.4 CONCLUSION AND RECOMMENDATION

Even though the best size of fish (at harvest) 127.8g was observed under Treatment I (25 fish/m³) of experiment 6.2.1; based on the total fish production and the survival rate, Treatment III (75 fish/m³) was found to be the best under the prevailing conditions and management applied at Kigera III Reservoir during the culture period (365 days).

It can be concluded that high quality supplementary feed is necessary in increasing production especially at higher fish stocking density as shown by the results under experiment 6.2.2.

In the Intermediate Basin experiment without supplementary feeding, treatment IV stocked with 100 fish/m³ had the best total fish production (1.976 kg/m³ in 150 days). It could also be concluded that natural productivity of the Intermediate Basin was capable of sustaining good growth of fish even at an initial density of 100 fish/m³ (or 1.5kg/m³) without supplementary feeding.

From the above conclusions, it could be recommended that:

(i) because of the low productivity of Kigera III Reservoir, a good quality pelleted feed (minimum of 20% crude protein) is needed for good growth of C. niloticus at a stocking density of 200 fish/m³ (or 1.14kg/m³). For a faster growth and higher total fish production, large size of fingerlings (about 20g/fish) must be stocked.

(ii) in the productive Intermediate Basin, extensive cage culture of tilapia should be encouraged. It may prove to be a viable alternative to the management of a resource as a fishery and it may be prudent to carry out some extensive culture of fishes in cages in conjunction with intensive lake-based fish rearing. This will reduce the environmental impact of wastes whilst increasing the profitability of the venture. Obviously, extensive cage culture in Lake Kainji should be of value for the rural communities.

Furthermore, it may be advisable to switch between semi-intensive and extensive cage culture at different times of the year, so as to take advantage of period of algal blooms in the lake. To date, there is no single private commercial cage culture on Lake Kainji.

CHAPTER 7

7.0 BREEDING EXPERIMENTS USING DIFFERENT MALE : FEMALE RATIOS OF OREOCHROMIS NILOTICUS BREEDERS AND HYBRIDIZATION TRIALS USING OREOCHROMIS NILOTICUS AND SAROTHERODON GALILAEUS IN FLOATING NET-HAPAS

7.1 INTRODUCTION

7.1.1 Tilapia Seed Production Experiment

Productive fish culture, like in terrestrical animal husbandry is heavily dependent upon adequate supply of good quality seed. One of the major constraints to increased fish production through Tilapia culture has been identified to be inadequate supply of the fish seed (Coche, 1982). Coche (1977 and 1979) opined that existing Tilapia breeding practices were inadequate and a new technology should be developed for selected tilapias. Several methods have been used to produce Tilapia seed (Shell, 1966; Radan, 1979; Guerrero and Garcia, 1983; Hughes and Behrends, 1983; Beveridge, 1984). Hughes and Behrends (1983) working on mass production of Tilapia nilotica seed in suspended net-enclosures concluded that the hapa system for T. nilotica appears to be more productive than most other systems.

Among factors considered to be important in fish seed production are brood fish age and size,

brood fish stocking density, brood fish sex ratio, brood fish nutrition, frequency of removing brood fish and/or seed from the brooding unit, types of container, water quality and rate of water exchange (Silvera, 1978; Berrios-Hernandez, 1979; Lee, 1979; Coche, 1982; Mires, 1982).

Research Scientists of South East Asian Fisheries Development Centre(SEAFDEC), Laguna Lake Development Authority (LLDA), and various Universities, since the late 1970s and early 1980s experimented (considering breeders sex ratio, density, etcetera) with lake-based hatcheries and nurseries (net-hapas) such that today, there are several commercial lake-based and Tilapia fry and fingerlings units in operation on some major lakes in the Philippines (SEAFDEC, 1982; 1982; Beveridge, 1987). By this approach, the Tilapia fingerlings needs of that country were being met as much as possible.

In Nigeria, there is no record of such experiments in the use of lake-based hatcheries and nurseries utilizing net-hapas for tilapia seed production in spite of the immense potentials of Tilapia cage culture in the country (Otubusin, 1983; 1989).

7.1.2 Hybrid Tilapia (seed) Production Experiment

Within the genera Tilapia, Sarotherodon and Oreochromis there are numerous species of which only a few have been used for culture work. In Lake Kainji, Nigeria, Sarotherodon galilaeus is the most abundant of the tilapias, followed by Oreochromis niloticus (Johnson, 1974; Akintunde, 1976). The latter was observed to have a better growth rate than the former (Bardach et al., 1972).

In most Tilapia species, it has also been observed that the male grows faster than the female (Fryer and Iles, 1972). Guerrero (1985) opined that the faster growth of Tilapia hybrids over their parent stocks may be partly explained by the higher percentage of males in the former. In recent years, S. hornorum has become a popular species for transplantation because of its suitability for the production of all-male hybrids (Lovshin and Da Silva, 1975). Some work has been done on the hybridization of tilapia species (Bard, 1960; Elder and Garrod, 1961; Fishelson, 1962; Kuo, 1969; Al-Daham, 1970; Chen and Tsuyuki, 1970; Hine et al., 1971; Lovshin and Da-Silva 1975; Mires, 1977; Lee, 1979; Hsiao, 1980; Bautista et al., 1981; Abella, 1982) and particularly on the interspecific cross Sarotherodon (Oreochromis) niloticus x Sarotherodon galilaeus (Wohlfarth and

Hulata, 1981). These studies, however, were reportedly carried out in tanks or aquaria (Mires, 1982). Wohlfarth and Hulata (1981) also reported that crosses between S. galilaeus and maternal mouth brooders have recently been carried out artificially.

Also in line with the general aims and objectives of this study on fish seed production in cage system, experiments were designed and conducted to determine the effect of hybridization of Sarotherodon galilaeus and Oreochromis niloticus (locally available commercially important Tilapia species) on the spawning frequency and fry production potential (the number and growth) in the floating net-hapa system in a drinking water reservoir (Kigera III).

7.2 MATERIALS AND METHOD

7.2.1 The Effect of Male : Female Ratio of Oreochromis niloticus breeders on fry production in floating net-hapas

This experiment was carried out in Kigera III Reservoir (Figure 3.1), already described under section 3.2. A module consisting of a 6m x 6m raft with 16, 1.25m x 1.25m apartments fittable with 1m x 1m net-hapas was used (Plate IV). The construction procedures for raft and hapas are as described under sections 3.3.1.2 and 3.3.2.1 respectively. The experiment consisted of three

treatments: I, 1 male : 1 female (12/m³); II, 1 male : 3 females (12/m³); III, 1 male : 5 females (12/m³). The breeders (average weight, 124.2g for males and 66.2g for females) were sexed as described for Sarotherodon mossambicus by Maar et al. (1966) and stocked randomly in net-hapas late evening (between 20.00 - 22.00 hr) according to the treatments above on 2 April, 1986.

The breeders were fed with 50% blood meal in pelleted feed (49.7% protein) twice daily at 5% of their biomass. The composition and proximate analysis of the feed are as described under section 5.2.4 (Tables 5.1 and 5.11). The procedures for the fish feed preparation and fish feed proximate composition determination also are as described under sections 3.5 and 3.6 respectively. Sampling for the number of hatchlings (fry) per hapa was carried out immediately the fry were observed to be schooling within the hapa. The breeders were transferred to a holding hapa in order to facilitate the harvest and counting of the fry. The breeders were later restocked in their initial hapa to continue the breeding experiment. However, the fry were held in separate hapas for nursing to fingerling size.

The breeders were also sampled every month for changes in body weight (growth) and the feed ration

was adjusted accordingly. Some physico-chemical parameters of the water at the site of the experiment were monitored as described under section 3.8.

7.2.2 Experiments on the Hybridization of Oreochromis niloticus and Sarotherodon galilaeus in floating net-hapas

The experiments were carried out in Nigera III Reservoir (Figure 3.1), which had earlier been described under section 3.2. A module of 6m x 6m bamboo raft with 16, 1.5m x 1.5m apartments fittable with 1.0m x 1.0m net-hapas was used for these experiments. The construction procedures for the raft and the net-hapas are as described under sections 3.3.1.2 and 3.3.2.1 respectively.

A short preliminary run (1st experiment) using S. galilaeus (SAG) and O. niloticus (ORN) was made prior to the actual experiments (2nd and 3rd experiments). The breeders used in these experiments were obtained by beach-seining at Monai Bay (about 5 km away from Dogongari Bay along Lake Kainji, Figure 3.1). The breeders were acclimatized in large holding net-cages (3m x 3m x 2.75m) the type described in Figure 3.6c and Plate VI. During the two-week acclimation period, the breeders were fed sparingly with pelleted feed. The fish species, S. galilaeus (SAG) and O. niloticus (ORN) (Plates vii and viii respectively) had earlier been described under section 3.4. Their breeders (average weight,

ORN: Male, 113.4g; Female, 46.1g and SAG: Male, 103.4g; Female, 36.4g) were sexed as described for Sarotherodon mossambicus by Maar et al. (1966). The breeders were stocked randomly in net-hapas (1m x 1m x 1m) in the early morning (between 06.00 - 08.00 hr) of 3 April, 1987 (for the preliminary run i.e. 1st run), and 13 June, 1987 and 6 February, 1988 for the 2nd and 3rd experiments respectively. The following treatments were used:

I. All ORN breeders, 1 male : 3 females ($12/m^3$)

II. All SAG breeders, 1 male : 3 females ($12/m^3$)

III. ORN males : SAG females in the ratio 1 : 3 ($12/m^3$)

IV. SAG males : ORN females in the ratio 1 : 3 ($12/m^3$).

The breeders were fed 10% blood meal in pelleted feed (31.34% protein, Tables 5.1 and 5.11, as described under section 3.5) twice daily at 5% of their biomass. Sampling for the number of hatchlings (fry) per hapa was done immediately after fry were observed to be schooling within the hapa.

The fry from the 2nd experiment (each first spawning) were then transferred to nursery hapas and stocked at the rate of 20/hapa (1m x 1m x 1m size) and fed finely ground (powdered) corn bran at

the rate of 20% of their biomass to study their growth potential. The fish were only sampled at stocking and at harvest (end of culture period) in order to avoid any mortality as a result of sampling stress.

Some physico-chemical parameters of the water at the culture site were monitored during the experimental period as described under section 3.8.

7.3. RESULTS

7.3.1 The Effect of Male : Female ratio of Oreochromis niloticus breeders on fry production in floating net-hapas

The results of some physico-chemical parameters of the water during the fry production experiments are shown in Table 7.1. Table 7.2 shows the summary of results of the effect of male : female ratio of O. niloticus breeders on fry production in floating net-hapas. School of fry was first observed 18 days after stocking in treatment II (M : F, 1 : 3) but 38 and 61 days after stocking in treatments III (M : F, 1 : 5) and I (M : F, 1 : 1) respectively. The highest total fry production was recorded in treament II (2001), followed by treatment I (1800) and least in treatment III (670). But the highest number of spawnings took place in treatment II (4 times), followed by treatment III (2 times) and least in treatment I (only once). The average number of fry per spawn in treatments I, II and III were 1800,500 and 335 respectively while the average

Table 7.1 Range and Mean of the physico-chemical parameters of the water during the fry production experiments (7.2.1).

Parameters	Range	Mean
Water temperature (°C)	25.0 - 34.0	29.0
pH	7.8 - 8.3	8.1
Dissolved Oxygen (mg/l)	3.01 - 5.68	4.35
Transparency (m)	0.45 - 0.75	0.54
Primary productivity (g C/m^2/day)	0.33 - 2.34	1.34

Table 7.2 Fry production of Oreochromis niloticus in floating net-hapas for 67 days.

Treatment	Male (M)	Female (F)	No. of fry produced	Average No. of fry/ spawn	Average No. of fry/F	Average No. of fry/ month	Average Wt. gain/ breeder (g/d) M	F	Spawning frequency/ month
M I									
M : F, 1 : 1	106.0(6)*	72.0(6)*	1800(1)**	1800	300	900	0.81	0.27	0.4
II									
M : F, 1 : 3	116.7(3)*	66.7(9)*	2001(4)**	500	222	1000	0.75	0.08	1.8
III									
M : F, 1 : 5	150.0(2)*	60.0(10)*	670(2)**	335	67	335	0.33	0.07	0.9

* Number of breeders in parenthesis

** Number of spawnings in parenthesis.

number of fry per female breeder followed a similar trend, 300, 222 and 67 respectively. Treatment II recorded the highest average number of fry produced per month (1000), followed closely by treatment I (900) and least in treatment III (335). Within the 67-day experiment, the breeders in treatment I had the highest average growth rates (g/d) of 0.81 for male and 0.27 for female; followed by treatment II (0.75 for male and 0.08 for female) and least in treatment III (0.33 for male and 0.07 for female) (Table 7.2).

7.3.2 Experiments on the hybridization of Oreochromis niloticus (ORN) and Sarotherodon galilaeus (SAG) in floating net-hapas

Table 7.3 shows a summary of the results of the preliminary (1st) experiment on Tilapia hybridization. School of fry was first observed in treatment IV (Males SAG vs female ORN) 19 days after stocking. Within the 70 days in which this preliminary run lasted, spawning occurred three times in treatment IV at intervals of approximately 3 weeks (23.3 days). The total fry production in treatment IV was 175 with an average number of fry per spawn of 58. The number of fry counted ranged from 18 to 107. Surprisingly, no spawning was observed in the other three treatments (Table 7.3).

The results from the second run are presented in Table 7.4. Spawning occurred in all the

Table 7.3 Fry production in the preliminary (1st) run of *O. niloticus* x *S. galilaeus* hybridization experiment for 70 days.

Treatment	Sex Ratio (M : F)	Mean weight (g) M	Mean weight (g) F	No. of fry produced	Average No. of fry/spawn	Spawning frequency/ month
I						
All ORN	1 : 3	150.0	76.7	-	-	-
II						
All SAG	1 : 3	83.3	81.1	-	-	-
III						
Male ORN, Female SAG	1 : 3	130.0	83.3	-	-	-
IV						
Male SAG, Female ORN	1 : 3	93.3	83.8	175(3)*	58	1.3

* Total number of spawnings in parenthesis

\- No spawning observed

M = Male, F = Female

Table 7.4 Fry production in the second run of O. niloticus x S. galilaeus hybridization experiment for 102 days.

Treatment	Sex Ratio (M : F)	No. of fry produced	Average No. of fry/ spawning	No. of fry/ female	Spawning frequency/ month
I					
All ORN	1 : 3	1352(6)*	225	150	1.9
II					
All SAG	1 : 3	325(3)*	108	36	0.9
III					
Male ORN, Female SAG	1 : 3	51(2)*	26	6	0.6
IV					
Male SAG, Female ORN	1 : 3	777(5)*	155	86	1.5

* Total number of spawnings in parenthesis.

treatments in this run. The highest fry production, 1352 was recorded in treatment I (males ORN x females ORN), followed by treatment IV (males SAG x females ORN) 777; then treatment II (males SAG x females SAG), 325 and least in treatment III (males ORN x females SAG), 51. The total number of spawnings during the experimental period was highest in treatment I (6); followed by treatments IV, II and III which were 5, 3 and 2 respectively. The trend in the average number of fry per spawning, number of fry per female breeder, and spawning frequency per month was similar to that of the total number of fry produced and total number of spawnings viz, in descending order:

treatment I > treatment IV > treatment II > treatment III (Table 7.4).

Table 7.5 gives the summary of the results of the third run of the Tilapia hybridization experiment. The results were similar to those recorded in the second trial. Treatment I gave the highest total fry production, followed by treatment IV but treatment III was superior to treatment II. The trend in the average number of fry per spawning and number of fry per female breeders was likewise similar to that of the total number of fry produced viz. in descending order: treatment I > treatment IV > treatment III > treatment II i.e. highest in treatment I and least in treatment II (Table 7.5).

Table 7.5 Fry production in the third run of the hybridization experiment for 10...

Treatment	Sex Ratio (M : F)	No. of fry produced	Average No of fry/spawning	No. of fry/female	Spawning frequency/ month
I All ORN	1 : 3	2011(5)*	402	233	1.7
II All SAG	1 : 3	47(1)*	47	5	0.3
III Male ORN, female SAG	1 : 3	217(2)*	109	24	0.6
IV Male SAG, female ORN	1 : 3	895(5)*	179	99	1.7

* Total number of spawnings in parenthesis.

Both the total number of spawning during the experimental period and the spawning frequency per month were similar for treatments I and IV whereas, treatment III was superior to treatment II considering the two parameters (Table 7.6).

Appendix 4 gives a pooled summary (of Tables 7.4 and 7.5) which helps to present a very clear picture of the tilapia hybridization experiments. The trend in the total number of fry produced, average number of fry per spawning and the number of fry per female was similar viz. in descending order: treatment I > treatment IV > treatment II > treatment III. Generally, the total number of fry produced, total number of spawnings during the experimental period, average number of fry per spawning, number of fry per female breeder and the spawning frequency per month were higher in the crosses (treatments) involving females CAN than in those involving females SAG (Appendix 4).

7.3.3 Growth Performance of pure-bred and hybrid fry in floating net hapas

Table 7.6 gives the summary of rearing of the fry from the four treatments of the second run in floating nursery net-hapas. At the end of the 56-day rearing period, treatment III recorded the highest average final weight, 2.43g, followed by treatment I, 2.03g, then treatment II, 1.95g and least in treatment IV, 1.64g. The trend in average final

Table 7.6 Results of rearing fry produced from treatments I, II, III and IV (of Experiment 7.2.2) in nursery floating hapas for a period of 56 days.

Treatment	Average Wt. (g) Initial	Final	Average daily Wt. gain (g/d)
I			
All ORN	0.03	2.03	0.036
II			
All SAG	0.02	1.95	0.034
III			
Male ORN, female SAG	0.03	2.43	0.043
IV			
Male SAG, female ORN	0.02	1.64	0.029

weight was similar to that of the average daily weight gain (i.e. growth rate in g per day) viz in descending order: treatment III > treatment I > treatment II > treatment IV i.e. growth rate highest in treatment III and least in treatment IV. Generally the average final weight and growth rate per fish per day were higher in crosses (treatments) that involved male O. niloticus (i.e. treatments I and III) than in those that involved male S. galilaeus (i.e. treatments II and IV, Table 7.6).

7.4 DISCUSSION

7.4.1 The Effect of Male : Female ratio of O. niloticus breeders on fry production in floating net-hapas

7.4.1.1 Spawning frequency/fry production

Spawning frequency often has a direct relationship with total number of fry produced. On the other hand the total number of fry produced is directly related to the fecundity of the fish (Hires, 1982). Trewavas (1973) opined that fecundity of Oreochromis niloticus varies considerably with the size of the brood fish. Invariably the size range of breeders (both male and female) used in all the treatments was very similar (Table 7.2). The breeders size range was quite close to the recommended range of 50 - 100g for fry production in net-hapas by Guerrero and Garcia (1983). This breeder size range (50 - 100g) was also recommended

for artificial spawning of S. mossambicus in aquaria by Rothbard and Pruginin (1975). Since there was no breeder size disparity, the highest fry production of 2001 and highest spawning frequency of 4 in 67 days recorded in treatment II (M : F, 1 : 3) could be attributed to the breeder sex ratio. Uchida and King (1962) and Guerrero and Garcia (1983) also observed that the 1 : 3 ratio of breeders (M : F) was more acceptable in terms of efficiency and highest reproductive rate. Even in rice paddies, Guerrero (1976) also recommended a breeder (M : F) ratio of 1 : 3 as the best combination for successful spawning.

In fact, the first sighting of fry in the net-hapas was in treatment II (M : F, 1 : 3) 5 days after stocking, but 38 days and 61 days after stocking in treatments I I and I respectively. The first spawning occurring in treatment II coupled with the same (treatment II) recording the highest number of spawning (4) during the 67-day breeding period undoubtedly confirm that the breeders ratio (M : F, 1 : 3) was the most appropriate for successful spawning and fertilization of the female eggs. On the other hand, in treatment III (M : F, 1 : 5) total fry production was least (670) as a result of the fewer number of males to females (2 : 10). The number of males to females in treatment I was the same and fertilization success was evident from the very high

number of fry produced (1800) even in just one spawning. Spawning frequency in treatment I was least (once) and timing of sighting the school of fry was very late (61 days). This could be attributed to the fact that the large number of males could have been "struggling" over the fewer females (only 6 compared to 9 and 10 in treatments II and III respectively). However, the highest average number of fry per spawn (1800) and the highest average number of fry per female breeder (300) recorded in treatment I could further confirm the high chances of successful fertilization of the eggs by the numerous number of males (6) in that treatment (I) compared with the low number of males (3 and 2) in treatments II and III respectively (Table 7.2).

7.4.1.2 Fry Production per female breeder

The highest total fry production expressed in terms of average number of fry/female was observed in treatment I, (300) and least (67) in treatment III (Table 7.2). These figures are lower than the fry production/female of 309 and 407 for male : female ratio of 1 : 5 and 1 : 3 respectively obtained by Guerrero (1979) during a 5-week breeding period. Madu and Ita (1984) on the other hand reported a total number of fry/female of 152 and 214 for M : F ratios 1 : 3 and 1 : 1 respectively feeding the breeders with a

diet of about 30% crude protein. Their figures are quite lower than 222 and 300 observed in treatment II (1 : 3) and treatment I (1 : 1) respectively (Table 7.2). The higher values obtained in this experiment may be as a result of the richer pelleted feed (50% crude protein) fed to the breeders coupled with the favourable physico-chemical parameters observed throughout the experimental period (Table 7.1). Guerrero and Garcia (1983) observed that the temperature range of 20.5 - 33.5°C; dissolved oxygen range of 6.7 - 13.2 ppm and net productivity of 0.45 - 8.31g C/m²/day were ideal for Tilapia seed production in a lake-based hatchery. The floating hapas used in this experiment were regularly flushed by the flow of water through them removing uneaten food and metabolites thus maintaining a good water quality as observed in Table 7.1.

7.4.1.3 Average number of Fry/month

The variation in average seed production per month under the different treatments (Table 7.) could be attributed to a combination of factors: variability in fecundity of individual females (Mires, 1982), differences in the spawning frequency of individual females (Lee, 1979), and the relative asynchrony of spawning cycles between individual females (Jalabert and Zohar, 1982). However, the mean number of fry produced per month in the three treatments, 745

(range 335 - 1000) was comparable to the monthly fry production of 880 fry/m^2/month obtained by Guerrero (1979) using cage spawning in the Philippines. But monthly fry production in this experiment were better than the production of 4.2 fry/m^2 in ponds reported by Campbell (1978) using supplementary feeding and 3 fry/m^2/month in a 350m^2 pond by Lovshin (1982).

7.4.1.4 Growth rates of breeders

The breeders in the three treatments were observed to grow throughout the experimental period (Table 7.2). But for both male and female breeders in the treatments, generally the growth rates decreased as the male : female ratio decreased i.e. the highest growth rates (g/d) (0.81 for male and 0.27 for female) were recorded in treatment I (M : F, 1 : 1), followed by treatment II (M : F, 1 : 3) and least in treatment III (M : F, 1 : 5). The males generally grew faster than the females in all the treatments. This observation agreed with that of Fryer and Iles (1972). Balarin (1979) opined that the lower growth rate in females during breeding was due to loss through egg spawning and not to fasting as was once thought. However, Huet (1972) and Guerrero (1983) were of the opinion that male tilapia grows faster than the female because where there is mouth incubation (as with female O. niloticus), during the incubation period the female does not eat at all.

7.4.2 Experiments on the Hybridization of O. niloticus (ORN) and S. galilaeus (SAG) in floating net-hapas

7.4.2.1 Preliminary (1st) Hybridization Experiment

Fishelson (1988) expressed the opinion that these two genera (Oreochromis and Sarotherodon) exhibit different reproductive behaviour and hence do not hybridize voluntarily. It was interesting that the cross, SAG male x ORN female (treatment IV) was the only one that recorded spawning success in the first hybridization experiment. The fact that spawning took place three times in this cross (treatment) within the 70-day experiment proved that O. niloticus could interbreed with S. galilaeus (Table 7.3). Even though Hepher cited in Trewavas (1982) was also of the opinion that 'it is very difficult to cross S. galilaeus with O. niloticus, the observations made in this experiment (especially including those in the second and third hybridization experiments) have proved otherwise.

Yashouv and Chervinski (1959) cited by Wohlfarth and Hulata (1981) reported the only documented cross involving the biparental mouth brooder S. galilaeus (S. niloticus x S. galilaeus) which was later doubted by its authors (Peters and Brestowsky, 1961). The uniqueness of these hybridization experiments being reported is that the crosses between S. galilaeus and O. niloticus were carried out (naturally) in floating

net-hapas in a drinking water reservoir which is closer to nature than the aquaria or tanks used by other workers (see Table 2.4 for references). However, Fishelson (1988) reported that crosses between S. galilaeus and maternal mouth brooders have recently been carried out by artificial fertilization.

The timing of the first observation of fry (i.e. 19 days after stocking) in treatment IV is similar to the observation made under section 7.3.1 (treatment II, Table 7.2) for tilapia (O. niloticus at M : F ratio of 1 : 3) fry production. It was surprising that no spawning was observed in the other three treatments. In treatment I (all ORN breeders) at least some spawning was expected, as observed under section 7.3.1 (Table 7.3), but none occurred. The lack of spawning in all the treatments except treatment IV in this preliminary run may be as a result of incompatibility of the newly-matched breeders in the intra and inter-specific crosses coupled with initial variability in the fecundity of the individual females (Mires, 1982).

7.4.2.2 Spawning success in the second and third hybridization experiments

(a) Spawning frequency/No of fry per female

The spawning frequency per month in the treatments could be an indication of the spawning success of the fish in each treatment. The spawning frequency per

month and number of spawnings per treatment during the period were observed to be higher in crosses (treatments) that involved female O. niloticus (i.e. treatments I and IV) (Appendix 4). Even in the preliminary run, it was only treatment IV that recorded any spawning and at a frequency of 1.3 (Table 7.3) comparable to 1.6 observed in treatment IV of experiment 7.2.2. This observation involving female ORN parent is contrary to that of Lessent (1968) who found differences in fecundity between crosses when hybridizing O. niloticus and S. macrochir and that hybrids were obtained only irregularly when O. niloticus was the female parent. The spawning frequency/month of 1.8 recorded in treatment I (all ORN at M : F ratio of 1 : 3) (Appendix 4) is consistent with the spawning frequency per month (1.8) also observed in a very similar treatment during another tilapia fry production experiment (treatment II; ORN, M : F, 1 : 3 in Table 7.2). It was therefore not surprising that the M : F breeders ratio of 1 : 3 was also used in the hybridization experiments. On the other hand, spawning frequency per month was lower in those crosses (i.e. treatments II and III) that involved S. galilaeus breeders. In fact the spawning frequency/month of 0.6 was consistent for both treatments (II and III) (Appendix 4). This variability in the spawning frequency per month in the four treatments definitely could be attributable to breeding behaviour of the fish species concerned (especially

the females as observed in this study). On the other hand, differences in the spawning frequency (for SAG female or ORN female - involved treatments) and number of fry per female could be as a result of the differences in the fecundity of the female fish. Fecundity (eggs/female) of S. galilaeus was observed to be about 5,000/year (Fryer and Iles, 1972) while that of O. niloticus was 700 - 2,000/spawn (Lowe-McConnell, 1955; Jhingran and Gopalakrishnan, 1974). It was therefore not surprising that the number of fry per female ORN in treatments I and IV were higher than those of female SAG in treatments II and III (Appendix 4).

The mean spawning frequency per female in treatments I and IV were significantly different ($P < 0.05$) from those of the other treatments (II and III). Whereas, only the mean number of fry/female in treatment I was significantly different ($P < 0.05$) from those of the other three treatments.

(b) *Fry Production*

As was discussed for the number of fry produced per female and the spawning frequency per month, breeding success as evident from the average number of fry produced and the average number of fry/spawning was much higher for crosses that involved female O. niloticus (i.e. treatments I and IV) (Appendix 4). This observation can be attributed to the fecundity and

parental care exhibited by the different species. Trewavas (1983) observed that both sexes of S. galilaeus brood while only the female O. niloticus broods. Fryer and Iles (1972) reported the fecundity (eggs/female) of S. galilaeus to be about 5000/year while that of O. niloticus was 700 - 2000/spawn (Lowe-McConnell, 1955; Jhingran and Gopalakrishnan, 1974). Obviously most of recorded successful hybridization experiments in ponds and tanks involved maternal mouth brooders (e.g. S. niloticus) and another maternal mouth brooder (e.g. S. macrochir) (see Table 2.4 for details and references). Trewavas (1983) observed that most tilapias were mouth brooders.

Generally, considering the female parents, the mean number of fry produced and mean number of fry/spawn from intraspecific crosses were higher than those from interspecific crosses (i.e. mean number of fry produced under all ORN > female ORN x male SAG while all SAG > female SAG x male ORN) (Appendix 4). This observation corroborates that of Lee (1979) who working with S. aureus, S. niloticus and S. hornorum obtained fewer fry from hybrid combinations (interspecific) than from intraspecific spawns. Some possible reasons for the fewer (or low) fry production in interspecific crosses include: incompatibility problems in the crosses, differences in courting/spawning behaviour, too low density of broodstock, inappropriate broodstock

sex ratios and higher fry mortality (Fryer and Iles, 1972; Lee, 1979; Mires, 1982).

However, there were significant differences ($P < 0.05$) between the mean number of fry produced in treatment I and the means of all the other three treatments. Whereas there were significant differences ($P < 0.05$) between the mean number of fry/spawning in treatment I compared to treatments II and III only but not significantly different ($P > 0.05$) from treatment IV.

7.4.2.3 Growth Performance of pure bred and hybrid fry in nursery hapas

Since the percentage of males amongst the fingerlings (obtained from rearing the fry for 56 days) could not be easily determined at this age and size of 1.64 - 2.43g (Table 7.6), the differential growth cannot immediately be explained on the basis of percentage of males. Lovshin (1982) noted that hybrids are grown until they reach a sexable size of 50 to 100g per fish. Growth of fingerlings from the intraspecific crosses, i.e. all ORN breeders, all SAG breeders, was observed to be intermediate between those of the interspecific crosses, i.e. ORN males x SAG females; SAG males x ORN females. The growth performance of ORN males x SAG females hybrid fry (treatment III) was about 20% better than that of ORN pure-bred fry (treatment I). This observation is similar to that made by Pruginin (1967) who noted that hybrids of male

Tilapia mossambica x female Tilapia nilotica grew 30% faster than pure bred Tilapia nilotica in the pond over a 126-day growing period. Similarly, Fishelson (1988) observed that the growth performance of the F_1 progeny (ORN x SAG) was not lower than that of their parent in the brood and higher by 1[illegible] - 20% of that of pure S. galilaeus. In recent studies on ORN x SAG hybridization but by artificial fertilization, Fishelson (1988) observed that for the male ORN x female SAG cross, 95% of the F_1 progeny were male and 5% female while for the male SAG x female ORN cross 96% of the F_1 progery were male and 4% female. On the basis of these observations, the higher growth rate (evidence of heterosis or hybrid vigour) recorded in F_1 progeny of treatment III (male ORN x female SAG) could be attributed to the higher proportion of male fry and dominance of the higher growth rate of male ORN over female ORN (Fryer and Iles, 1972) and even male SAG (Bardach et al., 1972).

However, the growth of the F_1 progeny (hybrid) for the cross, male SAG x female ORN (treatment IV) was lower than that of the pure species progeny (all SAG, treatment II). Even though, no immediate explanation could be given for this observation, Lessent (1967) reported a similar result where the hybrid did not show a greater growth rate than the parent. He observed that growth rates of the progeny

of the cross (S. macrochir x S. niloticus) in his study were the same as those of the parents. Pruginin et al. (1975) also found no heterosis (hybrid vigour) in the growth rates of hybrids of S. niloticus x S. Aureus, S. vulcani x S. aureus and their pure species progeny. Generally, hybrid vigour has been reported by Hickling (1960) and Avault and Shell (1967) showed otherwise.

7. CONCLUSION AND RECOMMENDATION

Under the experimental breeding studies carried out, it could be concluded that:

(i) The production of Tilapia fingerlings (both pure bred O. niloticus, S. galilaeus and their hybrids ORN x SAG) in floating net-hapas is feasible.

(ii) The floating hapa method of tilapia fry production is more productive than all other outdoor hatchery methods. The tilapia (ORN) breeders (male : female) ratio 1 : 3 recorded the highest spawning frequency and highest fry production/month.

(iii) O. niloticus and S. galilaues were successfully

crossed in floating net-hapas. Breeding success as evident from the average number of fry/spawning and the spawning frequency/ month was much higher for the crosses that involved female parent, O. niloticus than those crosses involving females S. galilaeus.

(iv) Heterotis was demonstrated only by the hybric progeny of the cross, male ORN x female SAG.

(v) The growth of the fingerlings (pure bred) from the intraspecitic crosses i.e. all ORN breeders, all SAG breeders, was intermediate between those (hybrid progeny) of the inter-specific crosses, i.e. ORN males x SAG females; SAG males x ORN females.

Since fingerlings production is an area in most need of research, it is recommended that:

(a) further investigations be carried out to determine improved methods of consistently and economically producing Tilapia fingerlings (both pure bred and hybrids) on a commercial scale. But there is need for caution in the case of the hybrids

so that the natural pure stock in the wild will not be contaminated. It is emphasized that a location like Lake Kainji which was suggested to be a source of undisturbed populations of tilapias (Pullin, 1988) should be jealously protected.

(b) more information be generated concerning the genetics, reproductive behaviour and physiology of tilapia (especially O. niloticus and S. galilaeus) in relation to hybridization. This may yet lead to the discovery of the suitability of our local Tilapia species for the production of all-male hybrids just like S. hornorum, a popular species for transplantation for all-male hybrids (Lovshin and D'silva, 1991).

(c) electrophoretic and isoelectric focusing techniques or any other appropriate method be applied in order to determine the genetic constitution of the hybrids in particular and the status

ot the wild and cultured stock in general.

CHAPTER 8

8.0 FISH CULTURE STUDIES IN FLOATING CAGES (WITHOUT SUPPLEMENTARY FEEDING IN A SEWAGE POND

8.1 INTRODUCTION

Waste water aquaculture as a possible means of water renovation, environmental protection and food production had all along been practised in some countries and is even receiving serious attention in future planning in some arid countries (Allen and Hepher, 1976; Gaigher; 1983). As human population increases protein requirements also increase. A art from human sewage, other types of organic waste from factories and other related industrial set-up can also be expected to increase. Studies have shown that all these forms of organic waste can be utilized for fish production although there is a general lack of information on waste water aquaculture technology (Gaigher, 1983). Otubusin (1989) enumerating some definite advantages of cage fish culture system reported inter alia that the system can be used not only primarily for producing high quality protein cheaply, but also for cleaning up eutrophic water bodies through the culture and harvesting of caged planktivorous fish species as practised in Malaysia and Singapore.

In Alabama, U.S.A., Sarotherodon aureus were cultured in experimental floating cages in ponds (in which other fish were also cultivated) fertilized regularly to develop either moderate or dense plankton blooms. In West Java (Indonesia), common carp, Cyprinus carpio are cultured on a commercial scale in fixed cages placed in canals and streams heavily enriched by agro-industrial and domestic effluents. This technology has since been applied to tilapias also, even though on a relatively small scale (Rabelahatra, 1979). In the Philippines, large scale commercial tilapia/milk fish culture in fixed cages and pens is carried out on a eutrophic natural water body, Laguna Lake (900 km² surface area) which is fed by industrial and domestic effluents from Manila, the capital city (population 6 million plus). Moye et al. (1986) at New Bussa, Nigeria reported a favourable use of a waste water in common carp/tilapia (Sarotherodon galilaeus) production by directly stocking the said waste water. The experiments reported under this chapter were carried out utilizing the same waste water in order to determine its potential fish production (Sarotherodon galilaeus) at different stocking densities in floating net-cages.

8.2 MATERIALS AND METHOD

The site used for the experiments was the NEPA sewage pond (0.4 has surface area) situated within New Bussa township (Figure 3.1 and Plate I). Other

details about the sewage pond are as described under section 3.2.4. Two modules of 6m x 6m raft each with sixteen, 1.5m x 1.5m apartments fittable with 1m x 1m x 1.25m (210/9, 25.4mm mesh) net-cages were used for the experiments. The construction procedures are as described under section 3.3.1 and 3.3.3.

Two separate studies were carried out but using the same fish species - Sarotherodon galilaeus.

8.2.1 The Effect of Stocking Densities (20-80 fish/m³) on Sarotherodon galilaeus Production in Floating Net-cages in a Sewage Pond

Eight apartments of one of the modules described above were used for this study. S. galilaeus fingerlings with mean weight of 10.2g were stocked on 27 April, 1989 using completely randomized design and replicated twice under the following treatments :

I, 20 fish/m³

II, 40 fish/m³

III, 60 fish/m³ and

IV, 80 fish/m³

50% of the fish were sampled thrice (i.e. at day 1, day 70 and day 150) during the 150-day culture period in order to minimize mortality through sampling stress. No supplementary feeding was given throughout the duration of the experiment. Some physico-chemical parameters of the sewage pond water were monitored as described under section 3.8.

8.2.2 The Effect of Stocking Densites (40-160 Fish/m³) on S. galilaeus Production in Floating Net-cages in a Sewage Pond

The methodology for this study is very similar to that of section 8.2.1. In fact, both studies were carried out simultaneously at the sewage pond. Eight of the apartments in the second module were used. S. galilaeus fingerlings with mean weight of 10.8g were stocked on 27 April, 1989 in the net-cages using completely randomized design and replicated twice under the following treatments:

I, 40 fish/m³

II, 80 fish/m³

III, 120 fish/m³

IV, 160 fish/m³

Likewise, no supplementary feeding was given throughout the 150-day experiment. 50% of the fish were sampled thrice (i.e. on day 1, day 70 and day 150) throughout the culture period in order to minimize mortality through sampling stress. Some physico-chemical parameters of the sewage pond water were monitored as described under section 3.8.

8.3. RESULTS

8.3.1 Performances of S. galilaeus Stocked at 20 -80 fish/m³ in Net-cages in the Sewage Pond

8.3.1.1 Survival

Table 8.1 shows the summary of results for experiment 8.2.1. The survival rates ranged from 60% to 80%. The highest mean survival rate of

Table 8.1 Results for S. galilaeus production at different stocking densities (20 to 80/m³) in floating net-cages in a sewage pond for 150 days culture period

Treatment	Average Weight (g) Initial	Final	Ave. Daily Wt. Gain (g/d)	Survival (%)	Production (kg/m³)
II	13.5	48.0	0.22	80.0	0.768
20/m³	10.0	52.0	0.28	70.0 a	0.728
	7.5	38.0	0.21	70.0	0.748 a
II	10.0	31.0	0.14	20.0	0.248
40/m³	9.5	32.0 b	0.15 b	100.0 a	1.280
	9.8	31.5	0.15	60.0 a	0.764 a
III	8.3	32.3	0.16	77.0	1.492
60/m³	10.0	23.5 b	0.09 b	83.0 a	1.170
	9.2	27.9	0.13	80.0 a	1.331 a
IV	10.0	31.0	0.14	83.0	2.058
80/m³	10.0	31.0 b	0.14 b	50.0 a	1.240
	10.0	31.0	0.14	67.0 a	1.064 a

Means in a column with the same superscript are not significantly different at 5% DMRT

80% was recorded in treatment III, closely followed by treatment I (75%), then treatment IV (67%) and least in treatment II (60%). The mean survival rates under the different stocking densities were not significantly different ($P > 0.05$).

8.3.1.2 Growth rates

Table 8.2 shows the results of some physico-chemical parameters of the sewage pond water during the experiments. The growth rates of fish in the different treatments were generally low. The highest mean growth rate was obtained in treatment I (0.26g/fish/day), while the other three treatments recorded almost similar growth rates ranging from 0.15g/d in treatment II; 0.14 g/d in treatment IV to 0.13g/d in treatment III (Table 8.1). The mean growth rate in treatment I was significantly different from the other three treatments ($P < 0.05$).

8.3.1.3 Production

Generally, the total fish production (kg fish/m^3) increased as the stocking density increased (Table 8.1). The highest mean production was recorded under treatment IV, 1.649 kg/m^3, closely followed by treatment III 1.331 kg/m^3, then treatment II, 0.764 kg/m^3 and least in treatment I, 0.748 kg/m^3. There were no significant differences in the mean production under the different treatments ($P > 0.05$).

Table 8.2 Range and Means of some physico-chemical parameters of the sewage pond water during the experimental period

Parameters	Range	Means
Water temperature (°C)	22.5 - 24.0	23.2
pH	6.9 - 8.2	7.6
Dissolved Oxygen (mg/l)	5.1 - 7.9	7.0
Transparency (m)	0.2 - 0.5	0.3
Pelagic primary production (g C/m³/day)	1.9 - 3.1	2.3

8.3.2 Performances of S. galilaeus Stocked at 40 - 160 Fsih/m² in Net-cages in the Sewage Pond

8.3.2.1 Survival

Table 8.3 gives the summary of results for experiment 8.2.2. The survival rates were generally high. The highest mean survival rate was recorded in treatment I (92.5%), followed closely by treatment IV (91.9%), then treatment II (83.8%) and least in treatment III (62.5%). There were no significant differences in the mean survival rates under the different treatments ($P > 0.05$).

8.3.2.2 Growth Rates

The growth rates of fish in all the treatments were generally low. The highest mean growth rate of 0.18g/fish/day was recorded in treatment I, followed by treatments III and IV, 0.10g/d and least in treatment II 0.07g/d (Table 8.3). The mean growth rates in treatments I and II were significantly different ($P < 0.05$).

8.3.2.3 Production

The total fish production in all the treatments were directly related to the different stocking densities. The highest mean production was recorded in treatment IV (3.652 kg/m³), followed by treatment III (1.868 kg/m³), then treatment II (1.499 kg/m³), and least in treatment I (1.357 kg/m³) (Table 8.3).

Table 8.3 Results for S. galilaeus production at different stocking densities (40 to 160/m³) in floating cages in a sewage pond for 150 days culture period

Treatment	Average Weight (g) Initial	Final	Ave. Daily Wt. Gain (g/d)	Survival (%)	Production (kg/m³)
I 40/m³	10.0	31.0	0.14	85.0	1.054
	10.0	41.5	0.21	100.0	1.660
	10.0	36.3^{ab}	0.18^{ab}	92.5^{a}	1.357^{a}
II 80/m³	11.3	24.8	0.09	82.5	1.637
	12.5	20.0	0.05	85.0^{a}	2.785
	11.9	22.4^{c}	0.07^{c}	83.8	1.868^{a}
III 120/m³	10.2	19.8	0.08	40.0	0.950
	10.8	27.3	0.11	85.0^{a}	2.785
	10.5	23.6^{bc}	0.10^{bc}	62.5	1.868^{a}
IV 160/m³	10.6	25.6	0.10	90.0	3.686
	10.6	24.1	0.09	93.8^{a}	3.617
	10.6	24.9^{bc}	0.10^{bc}	91.9	3.652^{a}

Means in a column with the same superscript are not significantly different at 5% DMRT

The mean fish production in treatment I was significantly different from the means of the other three treatments ($P < 0.05$).

8.4 DISCUSSION

Since the two experiments were carried out simultaneously and the treatments (stocking densities) were in multiples of 20, the pooled data (i.e. Tables 8.2 and 8.3 combined) will give an interesting picture for the discussion of the results of the experiments. The pooled results are as represented in Appendix 6.

8.4.1 Survival

No specific trend was shown in the survival rates under the different treatments. Gaigher (1983) in rearing *O. mossambicus* at densities of 17 to 435 fish/m^3 in cages without artificial feeding in various waste water treatment systems reported a range of survival rates of 60% to 100%. The range 62.5% to 91.9% obtained in these studies are comparable to those obtained by Gaigher (1983). Similarly, the mortalities recorded in these studies were due to sampling stress just as Gaigher (1983) reported a mortality rate of 40% (i.e. 60% survival rate) attributable to handling. The range of survival rates (62.5% to 91.9%) obtained in these studies was lower than the range (94.5% to 100%) reported in the Tilapia production experiment at stocking densities of 25 to 200 fish/m^3 in net-cages

for 150-day culture period at Kigera III Reservoir (Section 6.3.2. and Table 6.2). However, the range (62.5% to 91.9%) in these studies are better than the range (18% to 47.0%) recorded in Tilapia (O. niloticus) production at stocking densities of 25 to 100 fish/m^3 in net-cages without supplementary feeding for 150 days at Intermediate Basin, NEPA Kainji Dam Site, New Bussa (section 6.3.3. and Table 6.4). The disparity in the survival rates of fish at the sewage pond and the Intermediate Basin could be attributed to the different Tilapia species used. Ishak (1987) reported that O. niloticus is more sensitive to handling than S. galilaeus (which was used at the sewage pond). Doudcroff and Shumway (1970) and Warren et al. (1973) opined that supersaturation of pond waters from phytoplankton photosynthesis may adversely affect both growth and survival of some species of fish. The physico-chemical parameters of the waste water recorded in these studies (Table 8.3) were within tolerable limits for tilapia culture (Swingle, 1961; Balarin, 1979 and Guerrero, 1982), and therefore there was no adverse environmental effect on survival. There was no significant difference ($P > 0.05$) between the mean survival rates under the different treatments.

8.4.2 Growth Rates

Despite the fact that S. galilaeus stocked in

the cages at the sewage pond subsisted solely on natural food in the water medium, the range of growth rates (0.10 to 0.26g/fish/day) compared very well with the range (0.16 to 0.34g/fish/day) recorded under the supplementary feeding of O. niloticus in net-cages at Kigera III Reservoir (Table 6.1). Even though, Bardach et al. (1972) reported that O. niloticus have a better growth rate than S. galilaeus, the comparably good growth exhibited by the latter could be attributed to the adequacy of the natural productivity of the sewage pond water. Gaigher (1983) however, obtained a higher mean growth rate range of between 0.41g/fish/day to 1.39g/fish/day for O. mossambicus reared in cages (at densities of 17 to 435 fish/m^3) without aritificial feeding in various waste water treatment systems.

Aquino and Nielsen (1983) observed the relationship between growth rate of Oreochromis niloticus (initial average weight, 2g stocked at 50/m^3) in cages and the gross primary productivity in a lake of volcanic origin in the Philippines. They reported that the lowest weight increment of 0.12g/fish/day was observed when the gross primary productivity (GPP) was only 0.6g C/m^3/day while a GPP of less than 0.5g C/m^3/day gave no growth of fish. In the sewage pond studies, the range of growth rates/fish/day was 0.10g/d to 0.26g/d whereas the mean primary productivity observed was 2.3g C/m^3/day (Table 8.2). This was

similar to the value of 2.14g C/m³/day reported for another eutrophic lake (Laguna) in the Philippines (Bhent, 1981). The lower growth rates of S. galilaeus observed in the sewage pond could be attributable to the decreased efficiency of plankton utilization by the larger fish stocked (average initial weight, 10.5g) (Appendix 6) and the slower growth characteristic of S. galilaeus (Bardach et al., 1972). Gaigher (1983) observed that the efficiency of plankton utilization apparently decreased in larger fish.

The space factor was also evident in the growth rates of S galilaeus at the different stocking densities (20 - 150 fish/m³) (Appendix 6). The mean daily weight gain/fish was inversely proportional to the stocking density which corroborates the effect of the space factor as opined by Weatherly (1972). He stated that the degree to which fish are crowded together will affect growth.

The mean growth rates of 0.10g to 0.26g (Appendix 6) observed in these experiments were better than the growth rate of 0.05g/fish/day reported by Okoye et al. (1986) when they stocked S. galilaeus at 2274 per 400m² (i.e. about 6 fish per m²) directly into the same sewage pond. This means that the caged fish even though stocked at a higher density grew faster than the same species stocked directly into the

sewage pond. This observation is similar to that of Rifai (1980) who observed that growth rates of fish (O. niloticus) reared in cages were higher than those of fish reared in pond. This observation further confirmed the statement made by Warren (1971) that growth, as a response to the integrated activities of an organism as a whole, is a sensitive parameter of the suitability of the environment. The caged fish did not have to search extensively for food and thus more of the food eaten was converted into flesh. Moreso, even though the caged fish spawned, the eggs were often lost through the mesh of the net-cage (25.4mm) and there was no over-population in the cage (Pagan-Font, 1975). This was unlike the situation in the case of direct fish stocking into the sewage pond where at least 30,799 fish (S. galilaeus) were harvested apart from 173.8kg of fingerlings even though only 2274 fingerlings were initially stocked (Okoye et al., 1986). Within the 300 days (10 months) culture period Okoye et al. (1986) grew S. galilaeus from an average initial weight of 36.1g to 51.3g. But at the least stocking density of 20 fish/m^3 under the cage culture experiments, S. galilaeus grew from a mean weight of 11.8g to 50.0g in 150 days (i.e. 86.8g in 300 days). The mean growth rate of 20 fish/m^3 was significantly different from the means of all the other treatments ($P > 0.05$).

8.4.3 Production

Generally, the effect of the different stocking densities (20 to 160/m³) on total fish production can be seen at a glance studying the results in Appendix 6. The total fish production increased as stocking density increased even though with a corresponding decrease in the mean size of individual fish (i.e. 50.0g to 24.9g). The range (79.0g to 37.2g) of mean size of individual fish (O. niloticus) stocked at 25 - 200/m³ and fed with 18.9% crude protein feed (under section 6.2.2 and Table 6.3) was better than that of the sewage pond experiments for obvious reasons: O. niloticus naturally grows faster than S. galilaeus (Bardach et al., 1972) and moreso the former were given supplementary feed. It was not therefore, surprising that the range of mean total fish production (0.748 - 3.652kg/m³) for caged S. galilaeus at sewage lagoon was less than the range 1.976 - 7.039kg/m³ for O niloticus given supplementary feed in cages at Kigera III Reservoir. The successful fish production in cages in the sewage pond without supplementary feeding could be seen as a cost-saving exercise considering the fact that feed represents 40 - 60% of the total operating cost in intensive aquaculture (Coche, 1978; 1979; ADCP, 1983).

Considering the surface area (400m²) of the sewage pond, the least stocking density of 20/m² for the cage system and 6/m³ for the direct stocking into the sewage pond and assuming a survival rate of 75% for both systems, the estimated total fish production in the cage system, 520.8kg/400m³ is about 6 times higher than in the pond (direct stocking) system. If the highest stocking density of 160/m³ is considered using same factors (space, 400m³; survival rate, 75%; culture period, 300 days), the total fish production will be 1948.8kg for the cage system which is about 22 times higher than the pond system. The estimated total fish production in the cage system (at stocking densities of 20 to 150 fish/m³) could be compared to the claim that productivity from cage fish culture system could be as high as 10 to 20 times more than in the pond culture system (IDRC/SEAFDEC, 1979).

8.5 CONCLUSION AND RECOMMENDATION

i) Even though the experiments on the utilization of waste waters in fish production in cages were preliminary in nature, they do prove that cage culture of the local strain of *S. galilaeus* has potentials in waste waters aquaculture.

ii) The average daily weight gain per fish was inversely proportional to the fish stocking density whereas the total fish production increased as stocking density increased.

(iii) At the least stocking density of 20/m³ and other factors constant, the productivity of the cage system was observed to be about 6 times more than the pond system (direct stocking of S. galilaeus into the waster water).

It is recommended based on the experience from these experiments that:

(a) The harvested tilapia for human consumption should first be depurated such as is often done in cleaning bivalves before marketing (Hickling, 1962). This will serve as a precautionary measure against transmission of pathogenic organisms in waste water-reared fish. The portion of the harvested fish which could be too small for human consumption would need no depuration and could be used in fish meal production.

(b) Studies be carried out on utilization of waste waters in fish production in order to harness the immense potentials of such water bodies that abound in Nigeria. There could be some waste waters that cannot be used directly for fish culture. Therefore, an inventory should be carried out on the available waste waters in Nigeria and their adequacy for fish production.

(c) A holistic ecosystem approach involving all facets of aquaculture (especially cage system , water quality and pollution studies, pathobiological studies, waste water treatment techniques and all other related disciplines be adopted in the integrated waste water management and utilization.

CHAPTER 9

9.0 ECONOMICS OF FISH CULTURE IN THE FLOATING CAGE SYSTEM IN LAKE KAINJI AREA

9.1 INTRODUCTION

The major concern of the fish farmer is obviously to make profit from his farm. Profitablility per se naturally involves two factors aside from yield: the cost of production and the receipts (both cash and non-cash) from the sales of fish harvest. Ideally, careful economic analysis of profitability should be made at two different stages in fish farm management:

i) before establishing the farm in order to determine whether the investment is likely to be profitable and at what level of intensity the farm must operate in order to be profitable;

ii) during the continuing management of the farm to test whether, in fact, the operation is profitable and to examine ways of improving profitability.

In aquaculture economics, this can be done by examining the input-output relationships (of the production system) which depend upon the biology of the species and technology of production.

Even though, Chua and Teng (1980) noted that cage culture is one of the most productive aquaculture systems widely used for intensive fin fish culture, this system is yet to be used in Nigeria for commercial fish farming. Whereas, for example, in Malaysia, cage culture of estuary groupers (Epinephalus salmoides Maxwell) has been found to be of great commercial potential (Chua and Teng, 1977; ' 78) and many fish farmers have developed cage culture on a small scale. Undoubtedly, the situation in Nigeria can be attributed to lack of knowledge of the cage culture technology and equally its profitability.

The specific objective of this chapter therefore, is to provide information on the economics of fish culture in floating cage system in Lake Kainji Area and to recommend the fish cage culture technology appropriate for the use of fish farmers in inland waters of Nigeria.

9.2 BACKGROUND INFORMATION

The most vital local resource for the well-being of fish is water. Nigeria is blessed with about 12.5 million hectares of freshwater bodies (Ita et al., 1985). Ayeni et al. (1986) noted that less than 1% of these potential sites (water mass) is utilized for aquaculture. It is not surprising, therefore that the total annual production from aquaculture in Nigeria was 25,607 metric tons in 1989 (Federal Department of Fisheries, 1990). The vast Nigerian water bodies have

great potentials if they are developed and utilized in various appropriate aquaculture systems. For example, fish production from cage culture system by utilizing just 10% of the 2,542,150 ha of reservoirs and mining paddocks in Nigeria (Ita et al., 1985) was estimated at 1,653,846 metric tons (Ayeni et al., 1986). This production estimate is achievable if only the appropriate strategies are applied, among which is the giving of direct financial and technical assistance to aid peasant farmers who constitute about 30% of food producers (farmers, fishermen and fish farmers) in Nigeria (FAO, 1988). In capture fishery, the artisanal is however, still the most important sub-sector, consistently accounting for well over 90% of the total domestic production in Nigeria (West, 1986). It is therefore, logical to focus on the operation of small scale commercial production of fish (Tilapia) in floating cages as a basis of providing information on the economics of fish culture in floating cage system. Tilapia is the fish species used here for obvious reasons earlier given. The data and other pieces of information that are used in this economic analysis are based on the results, observations and experiences obtained from all the phases in the conduct of these studies around Lake Kainji Area which include:

i) the module consisting of 6m x 6m bamboo raft with sixteen, 1.5m x 1.5m apartments, fittable with sixteen, 1m x 1m x 1m net-

hapas was observed to be most suitable for Tilapia floating hatchery/nursery operations at both small, medium and large scale fish fingerlings production (Plate IV); 6.5m x 6.5m x 1.5m, anti-predator net-cage (210/9, 10mm mesh size) can be fitted to surround the hatchery/nursery module to prevent intrusion/destruction by aquatic predators

ii) the module consisting of 7m x 7m bamboo raft with four, 3.5m x 3.5m apartments, fittable with four, 3m x 3m x 2.75m net-cages (210/9, 12.7mm mesh size minimum) was observed to be ideal for Tilapia grow-out phase (Figure 3.6; Plate VI)

iii) for either hatchery/nursery or growout operations, more than one module can be linked together depending on the level of production: small, medium or large scale (Plate III)

iv) Black coloured 100-L plastic floats (product of Tate and Lyle, Ilorin, Kwara State) were found to be most durable (life span 5 years +) compared with green coloured (1 to 3 years) and white coloured (less than 1 year). Net-hapas were observed to have a life span of 3 - 5 years while net-cages

(knotted) could be used efficiently for 3 - 5 years also.

v) the presence of adequate natural food in the culture environment was observed to enhance the efficiency of supplementary feed for faster fish growth. For example, at Shagunu Bay along Lake Kainji, growth rates of 2.83 and 2.03 g/d were observed for Oreochromis niloticus and Sarotherodon galilaeus respectively (Table 4.3). The highest growth rate recorded for O. niloticus at Igera III Reservoir (an oligotrophic reservoir) was 0.72 g/d using groundnut cake in pelleted feed (section 5.2.5)

vi) Tilapias (both O. nilcticus and S. galilaeus) were observed to be relatively easy for culture (fingerling production, broodstock development and growout) and efficient in use of low cost feeds (sections 2.3 and 5.2.5)

vii) All the materials used for the cage culture studies were readily available in Nigeria. Their durability/life span are well known and their local sources have been identified (Appendix 7).

9.3 TILAPIA FRY AND FINGERLING PRODUCTION IN NET-HAPAS

A site that meets all or most of the requirements for Tilapia culture is envisaged for this project. Criteria for site selection for cage culture had earlier been enumerated under the chapter on review of literature.

For the small scale venture, 4 modules of 16-unit hapas/modules are needed for the hatchery operations while another 4 modules of 16-unit hapas/module are also needed for the nursery activities (Plate IV). Tilapia (Oreochromis niloticus) breeders with minimum average weight of 60g/fish for females and 100g/fish for males are stocked at the rate of 12 breeders/hapa and at a ratio of male:female, 1:3. The breeders are fed pelleted feed (20% CP minimum). School of fry is expected in the hapas around 18 days after stocking. Average monthly production of O. niloticus fry is 1000 pieces/net-hapa.

To produce Tilapia fingerlings, the fry were further reared in hapas at a density of 1000 per hapa and were fed with powdered feed (30% CP minimum) for fast growth until they were transferred to grow-out cages after about 2 months.

9.3.1 Economics of Small Scale Tilapia Fingerlings Production in Hapas

Four modules of 16-unit hapas (hatchery) and 4 modules of 16-unit hapas (nursery) are the minimum components for a profitable small-scale commercial venture.

The annual operating and maintenance costs and prospects of the venture are as shown in Table 9.1. The computations are based on the current prices of goods and services in Nigeria as at December 1991, and the followings:

i) Production period: 10 months

ii) Expected life span of hapas: 3 years

iii) Each module is surrounded by 6.5 x 6.5m x 1.5m (10-mm mesh) anti-predator net-cage. This is OPTIONAL if the site is not prone to aquatic predators.

iv) 50% (minimum) survival of fry to fingerlings

v) Labour will be supplied mainly by members of the co-operative group or farmers association or any other community operators of the project. Casual labour can be hired when needed.

vi) In spite of "cost prices squeeze" where prices of inputs increase faster than the price of out-put, the fluctuating supply and demand conditions will be used to make sure the venture is still profitable.

Table 9.1 Annual Operation and Maintenance Costs and Prospects of Small-Scale Commercial Tilapia Fingerlings Production.

Items	Unit Cost (₦)	Amount (₦)
A. FIXED COSTS		
(i)* 4 modules of 16-unit hapas (hatchery)	12,000	48,000
(ii)* 4 modules of 16-unit hapas (nursery)	12,000	48,000
(iii) Wooden boat (1)	5,000	5,000
(iv) Guard House/working shed	5,000	5,000
(v) 33⅓% annual depreciation on infrastructure		35,300
B. OPERATING COSTS		
(i)* Tilapia breeders, 3 sets (2,640 pieces)	5	13,200
(ii) Feed 500 kg	4	2,000
(iii) Night guard (1)	4,200	4,200
(iv) Maintenance/Repairs	2,000	2,000
(v) Miscellaneous (casual labour, buckets, scoop nets, scale, polythene bags etc)	5,200	5,200
(vi) Contingencies (Insurance etc)		5,320
TOTAL		173,220
C. Annual sale of 320,000 fingerlings	.50	160,000
	Year 1	Year 2
D. Total Cost of production	173,220	67,220
E. Gross Profit/Loss	−13,220	92,780
F. Return on Investment (%)	− 7.6	138.0

* If the farmers produce their own breeders and use a predator-free site, then the production cost will be greatly reduced after the first year of operation.

* Cost of modules includes cost of construction, transportation and installation.

9.3.2 Prospects

The return on investment (ROI) indicates a loss at the end of first year of operation. It however, became compensated by a high value (139.0%) at the end of the second year of the project (Table 9.1). Under good management, therefore, if a soft loan is taken from the bank for the project, it should be possible to amortize the loan in three years.

Since the demand for large quantity of good quality fish fingerlings for stocking commercial cages (when established as an industry) will be high, the operation of many small scale commercial hatchery/nursery will be a reliable and regular source of supply to meet this demand. This fingerling production system has the following advantages:

a) the modules can be transferred from one site to another for the continuation of the project (unlike ponds or concrete tanks).

b) it ensures total harvest of clean, high quality fingerlings unlike beach-seining of fingerlings in pond which is not total and also injures the fish. This (pond-seining) results in high mortality and the fingerlings are often soiled with mud.

c) harvesting of fingerlings from hapas is fast and requires only one or two persons

per hapa unlike pond-seining which requires many hands.

d) the system even though is very ideal for Tilapia fingerlings (pure bred and hybrids) production, was found suitable also for production of fingerlings of common carp (Cyprinus carpio) and mud catfish (Clarias gariepinus) (Otubusin et al., 1985)

The prospects of this small-scale fingerlings production project are therefore, quite high. Considering the cost of production, there will be need to avail of credit facilities in the government-owned Agricultural Banks at the lowest interest rate possible. This system of culture is very ideal for co-operative groups/societies, farmers associations or community development associations (CDAS). It is therefore, recommended for all local governments in the country where suitable sites are available. Technical consultations should however, be made before embarking on the project in order to forestall problems that could militate against the project (being a relatively new culture system in Nigeria).

9.4 TILAPIA TABLE-SIZE PRODUCTION IN NET-CAGES

A site with abundant natural food is proposed for this culture system in order to reduce production cost. Lake Kainji (already described earlier) has many ideal

sites (coves and bays) for this culture system e.g. Shagunu Bay (Figure 3.1).

Four modules of 4-unit cages per module are the minimum needed for the small-scale production project. Each module consists of 7m x 7m bamboo raft with four, 3.5m x 3.5m apartments fittable with four, 3m x 3m x 2.75m net-cages (210/9, 12.7mm mesh size). Each net-cage has an additional hapa bottom aside from being double-net-walled at the bottom (Figure 3.6; Plate VI). The high quantity of tilapia fingerlings for stocking the production cages in this project are expected to be met by the production from the small-scale fish seeds farmers. The fish feed can be produced by the farmer or purchased from reputable fish feed manufacturers in the country like National Institute for Freshwater Fisheries Research, New Bussa; Nigerian Institute for Oceanography and Marine Research, Lagos; Pfizer Nigeria PLC; Talon Nigeria Ltd, Lagos etc (Appendix 7). During algal blooms in the water body, supplementary feeding is suspended so as to avoid polluting the culture system.

9.4.1 Economics of Small Scale Table-size Tilapia Production in Net-Cages

The estimated annual production cost and return for the small-scale table-size Tilapia cage farming are shown in Table 9.2. The computations are based on the current prices of goods and services in Nigeria as at December, 1991 and the followings:-

Table 9.2 Estimated Annual Production Cost and Returns for small-scale table-size Tilapia farming in Floating net-cages.

Items	Unit Cost (₦)	Amount (₦)
A. FIXED COSTS		
(i)*4 modules of 4-unit cages	15,000	60,000
(ii) 1 Wooden Boat	5,000	5,000
(iii) Guard House/working shed	5,000	5,000
(iv) 33⅓% annual depreciation on infrastructure		23,310
B. OPERATING COSTS		
(i)*Fish seeds (80,000 pieces for 2 crops)	.50	40,000
(ii)*Feed, 10 tons	4,000	40,000
(iii) Night guard (1)	4,200	4,200
(iv) Maintenance/Repairs		5,000
(v) Miscellaneous (casual labour, buckets, scoop nets, scale etc)		5,800
(vi) Contingencies (Insurance etc)		19,000
TOTAL		207,310
C. Annual sale of 14,400 fish	15	216,000
	Year 1	Year 2
D. Total Cost of production	207,310	137,310
E. Gross Profit	6,690	78,690
F. Return on Investment (%)	4.2	57.3

* If the farmers can produce their own fingerlings and also the fish feed which together constitute about 84% of the operating costs, then production cost will be drastically reduced.

* Cost of modules includes cost of transportation, construction and installation.

i) Production period: 5 months/crop (2 crops in a year)

ii) Expected life span of net-cage: 3 years

iii) Stocking density: 100 fish/m^3; 200g/fish at harvest and 90% survival

iv) Only 22.5m^3 of the cage volume used

v) 2,500 fish actually stocked per cage per crop to allow for stocking mortality

vi) Size of fingerlings stocked: 20g average size per fish

vii) Labour will be supplied mainly by members of the co-operative group. Casual labour to be hired when necessary

viii) Galloping inflation in the cost of inputs will be taken care of by supply and demand conditions such that the venture will still be profitable.

9.4.2 Prospects

Economic viability of aquaculture (including cage culture) depends on the interplay of various complex factors. It is often the aim of fish farm operators to cut down production cost in order to increase the returns on investment. However, production cost is a function of operational skills which include selection of sites, fish species and the manipulation of the growth pattern of the stock and also the production capacity of the

culture system. It should not be surprising therefore, that the ability to achieve high production per unit area very often varies with the skill of the operators. The high return on investment (especially as from the second year of the project) given in Table 9.2 should therefore, not look exaggerated. The productivity of cage culture system in terms of fish yield had been known to be as high as 10 to 20 times more than pond culture considering the surface area and inputs (IDRC/SEAFDEC, 1979). For example, farming of the channel cat fish, Ictalurus punctatus in the U.S.A. showed that intensive culture in floating net-cages and fence enclosures gave the highest rate of returns on investment (ROI), 121% to 160% as compared to pond and raceway culture, 22% - 55% (Shang 1976). So also intensive culture of common carp in Japan recorded good returns on investment of 300 , whilst extensive culture in Poland showed that the ROI was only 3 (Shang, 1976). Even, extensive pen culture of milk fish Chanos chanos was found to be more lucrative than pond culture, the ROI were 140% and 11.5% respectively. The ROI of 57.3% as from the second year of the project (Table 9.2) is quite less than the minimum ROI of 121% obtained for intensive culture of channel catfish in cages and enclosures in the U.S.A. (Shang 1976).

The prospects of this culture system based on the number of modules recommended are quite high. Since the loan obtainable (about ₦150,000.00) is quite high, the project can be operated by co-operative groups, community development associations, groups of interested unemployed agriculture graduates and so on.

9.5 CONCLUSION AND RECOMMENDATION

Even though, cage fish farming is relatively new in Nigeria, this culture system undoubtedly has great potentials in drastically increasing fish production from the country's vast inland and marine bodies of water including mining paddocks.

The utilization of floating net-hapas and net-cages system for tilapia fingerlings and table-size fish production respectively were found technically feasible and economically viable especially when operated at small scale commercial level. Several local and nation-wide aquaculture activities (training/workshop and pilot cage culture operations) involving cage fish culture (DFRRI, 1988; Koinyan, 1988a; 1986b) attest to the evolution of fish cage culture technology appropriate for the use of fish farmers in inland waters of Nigeria. Since there are still technological gaps to be filled in the cage culture technology, concerted efforts at the three tiers of government, non governmental agencies (NGOs) and the public have to be mustered in order to achieve a total break-through.

It may sound surprising that Philippines which is now very famous for cage fish culture only had cage culture experiments started in 1973 in Laguna Lake (Delmendo and Baguilat, 1974) and commercial production of Tilapia mossambica in floating cage by the private sector in 1975 (Guerrero, 1979). It is therefore, recommended that:

i) All Institutions involved in cage fish culture research and development should be adequately funded to cary out more research on this seemingly new system of fish culture and also train the much needed technical manpower that would render extension services to would-be farmers in the localities.

ii) Government Institutions and non-governmental organisations (NGOs) involved in fish seed multiplication should intensify their activities in order to supply the large volume of fish fingerlings that will be regularly needed to stock the cage culture system.

iii) Government Institutions and appointed livestock and feed millers nation-wide and those involved in production of inputs like nets, floats etc, should be given incentives to step-up the production of these essential inputs and sell them at

affordable prices for use in the cage culture system.

iv) The appropriate arm(s) of the government should initiate the survey of the country's water bodies and then legislate on the use of water bodies at temporary ownership licence (TOL) for cage fish culture activities.

v) Financial and lending/banking Institutions should be approached by the government to allocate a reasonable proportion of their agricultural loan to fish farming. The Small-scale Farmers' Credit Scheme and Agricultural Insurance Scheme (which cover only rice, maize, poultry and cattle) launched in Kaduna some time ago (Koinyan, 1986b) could perhaps be extended to boost small-scale cage fish farming also.

vi) Finally, the Community Based Implementation Strategy (CBIS) which affords an effective grass root participation, as favoured by Directorate of Food, Roads and Rural Infrastructure (DFRRI) (Koinyan, 1988a) should be executed using small-scale fishermen/fish farmers grouped into Co-operative societies, Farmers' Associations or Community Development Associations (CDAS)

for the commercial cage culture project. These small-scale groups are in the best position to utilize the vast unpolluted water bodies in Nigeria for tilapia cage farming - which could be one practical solution to the problem of inadequate protein for the country's growing population.

CHAPTER 10

10.0 GENERAL SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

10.1 GENERAL SUMMARY AND CONCLUSIONS

The vast unpolluted inland freshwaters of Nigeria provide opportunities for use in fish production by means of cage culture practices. Farming of fish in cages had been traditionally practised for many years in several countries especially in Asia. Of the modern aquaculture systems, cage fish culture had been proven to be one of the cheapest to operate. Unfortunately, this innovative fish culture method has had practically no application in Nigeria even though some success had been recorded using this system of fish culture in some African countries like Egypt, Ivory Coast, Tanzania, Togo, Sierra Leone, Sudan and Niger Republic. Studies were therefore carried out at the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa around Lake Kainji area (between 1986 and 1991) with some specific objectives but an ultimate aim of evolving a fish cage culture technology appropriate for the use of fish farmers in inland waters of Nigeria.

Five sites around Lake Kainji area were used for the studies:

(i) The Intermediate Basin located between Kainji Dam and the northern end of Lake Jebba;

(ii) Dogongari Bay on the west of Lake Kainji near NIFFR Headquarters;

(iii) Kigera III drinking water reservoir within NIFFR Housing Estate;

(iv) National Electric Power Authority (NEPA) sewage pond in New Bussa township and

(v) Shagunu Bay, west of the middle basin of Lake Kainji.

Fourteen experiments were designed and carried out in line with the objectives of the studies. Two of the experiments were on the cage culturability of some commercially important fish species in Lake Kainji and a preliminary study on the growth of Clarias citharus in floating cages in two different sizes. The remaining twelve experiments were carried out using Tilapias (Oreochromis niloticus, ORN and/or Sarotherodon galilaeus, SAG) under the following broad titles:

(a) Feeding experiments using agro-industrial wastes and some other feedstuffs in different combinations in floating cages.

(b) Stocking densities experiments using O. niloticus with or without supplementary feeding in floating cages.

(c) Breeding experiments using different male : female ratio of ORN breeders and hybridization trials using ORN and SAG in floating net-hapas.

(d) Fish culture studies in floating cages (without supplementary feeding) in a sewage pond.

All the experiments were carried out in floating bamboo cages (with either net-hapas or net-cages). All the treatments were appropriately assigned to the cages using a completely randomized design and were also replicated appropriately. In experiments involving supplementary feeding, the fish were fed with powdered or pelleted feeds at either 20 , 10%, 5% or 3% of the fish biomass depending on the size of the fish (fry, fingerlings or juveniles/breeders), the objectives and duration of the experiment. The stocked fish were sampled appropriately for growth, survival and production (at harvest). Some physico-chemical parameters of the culture medium (water) and proximate analyses of the feeds were carried out as much as possible. The data obtained from the various experiments were analyzed using Analysis of Variance and Duncan's Multiple Range Test.

The highlights of results from the various experiments under the studies were as follows:

1. The module of 6m x 6m raft with sixteen 1.5m x 1.5m apartments fittable with sixteen, 1m x 1m x 1m net-hapas was observed to be most ideal for floating hatchery/nursery operations in fish fingerlings production especially Oreochromis niloticus, Sarotherodon galilaeus and their hybrids. An anti-predator net-cage (3/8" mesh size) had to be used to enclose each module to prevent intrusion of predators from the wild.

2. The module of 7m x 7m raft with four 3.5m x 3.5m apartments fittable with four 3m x 3m x 2.75m net-cages (knotted) was noted to be suitable for the grow-out. The net-cages for grow-out (normally double-netted at the bottom and with hapa netting sewn to the bottom inside afforded the caged fish a better utilization of the sinking pelleted feed.

3. The floating net-hapa system was found to be more productive than some other outdoor hatchery systems at NIFFR (i.e. outdoor concrete tanks and concrete raceways) for Tilapia fry production. The tilapia (ORN) breeders in Male : Female ratio of 1 : 3 at 12 breeders/m^3 gave the highest

spawning frequency and the highest fry production (1,000) per hapa per month.

4. The tilapia species (O. niloticus and S. galilaeus) were observed to hybridize voluntarily, naturally and easily in floating bamboo net-hapas at Kigera III drinking water reservoir. The total number of fry produced, spawning frequency, number of fry per female and the average number of fry per spawning were higher in the crosses involving female ORN than in those involving females SAG. The growth of the F_1 progeny from the intraspecific crosses i.e. all ORN breeders; all SAG breeders, was observed to be intermediate between those of the interspecific crosses, i.e. ORN males x SAG females, SAG males x ORN females.

5. Under the cage culturability of some commercially important fish species in Lake Kainji, the microphagous/ planktivorous C. citharus, O. niloticus and S. galilaeus recorded high growth rates (g/d), of 3.31, 2.83 and 2.03 respectively. Clarias gariepinus on the other hand, had a daily growth rate (g/d) of 3.28. C. citharus stocked in cages at Shagunu Bay (Lake Kainji) recorded a

higher growth rate (1.92g/fish/day) than those in cages at Kigera III Reservoir (0.9g/fish/day).

6. Under the feeding experiments, corn bran (fed as a single ingredient) was observed to give the best feed conversion ratio, FCR (6.53), highest average final weight and the fastest growth rate in nursing tilapia fry to fingerlings. The combination of corn bran and brewer's waste (in ratio 1 : 1) was observed to give the best FCR (4.28), fastest growth rate and highest average final weight in rearing tilapia fry to fingerlings in floating hapas. Whereas, the feed containing corn bran with constant amount of fish meal and premix recorded the best FCR (1.13), the fastest growth rate and highest average weight gain in rearing tilapia fry to fingerlings in floating cages.

In the grow-out phase the pelleted feed containing 10% blood meal was the most efficient in terms of total fish production, average final fish weight. While, groundnut cake in pelleted feed gave the best FCR (1.12), the highest average final weight

and the highest average daily weight gain in O. niloticus production in grow-out cages.

7. Under the stocking density experiments, even though the fish growth generally decreased with the increase in stocking density, the highest total fish production (5.09/kg/m³) was obtained at a stocking density of 75 fish/m³. The role of high quality supplementary feed in enhancing production even at higher fish stocking density was confirmed by the best fish production (7.039 kg/m³) obtained by stocking tilapia at 200 fish/m³. The natural productivity of the Intermediate Basin (NEPA Damsite) was observed to be capable of sustaining good growth of fish even at a stocking density of 100 fish/m³ without supplementary feeding.

8. Under the waste water cage culture experiments, it was observed that S. galilaeus has potential in waste waters aquaculture.

It could also be concluded from the foregoing that:

(i) The moon fish Citharinus citharus, with no previous record of use in cage culture and often described as a bottom-dweller survived and grew well in the floating

cages. This observation further confirmed an earlier observation that Citharinus sp. were no longer bottom-dwellers in Lake Kainji. In addition to the popular tilapias, C. citharus seems a potential candidate fish for cage culture considering its growth performance, fecundity, adaptability, late maturity (unlike tilapias), feeding at the base of the food chain.

(ii) The powdered feed containing 74% corn bran + 25% fish meal + 1% premix appears to be an efficient and economical feed for use in commercial tilapia fingerlings production in net-hapas. On the other hand, the pelleted diet containing 25% groundnut cake + 74% layer's concentrate/corn bran (in ratio 1 : 3) + 1% premix seemed ideal for table size (Tilapia) production in cages. Blood meal compounded at 10% plus other feed ingredients like corn bran was found suitable and promising in formulation of economically efficient Tilapia feed in cages.

(iii) At the highest tilapia stocking density of 200 fish/m^3, the highest fish production was enhanced by inclusion of

about 20% protein feed containing 10% blood meal + 69% corn bran and 1% premix. In the absence of supplementary feed, the abundance of natural food in the culture medium was advantageous to the growth of tilapia (O. niloticus) especially under extensive cage culture in Lake Kainji (e.g. at Intermediate Basin and Shagunu Bay).

(iv) Apart from the suitability of the floating net-hapa system in Tilapia fingerlings production, the system applied in a near-to-nature environment must have contributed to the voluntary and natural hybridization of O. niloticus x S. galilaeus which hitherto was reported in Israel to be very difficult.

(v) The experiments using waste waters in fish cage culture confirmed that productivity of cage system could be several folds (about 6 times in this case) higher than the pond system(e.g. direct stocking of S. galilaeus in the waste waters) considering the space and other inputs.

(vi) In spite of the newness of the cage culture system in Nigeria, it could be concluded undoubtedly that the system has great potentials in increasing fish

production from the country's vast water bodies (e.g. hydroelectric reservoirs, drinking water reservoirs, waste waters etc). The system (as hatchery/nursery and grow-out) was found technically feasible and economically viable and ideal for small scale commercial operations.

10.2 GENERAL RECOMMENDATIONS

For a rapid introduction of fish cage culture throughout the country, it is recommended that:

(a) The Federal Government of Nigeria should accord cage fish culture a high priority in the National Policy on Aquaculture.

(b) Institutions and centres involved in cage fish culture research should be generously funded to carry out more research on every aspects (especially fish feed formulation and fish seed production) of this culture system in order to fill the gaps in knowledge on the system.

(c) The promising indigenous fish species, C. citharus should be further investigated in the cage culture

system - for broodstock development, fingerlings production, and table-size production. Efforts should be geared towards the induced breeding (artificial or natural) of the fish for mass fingerling production.

(d) More hybridization (ORN x SAG) trials should be carried out to monitor parameters like the genetic constitution of the best growing F_1 progeny using electro-phoretic or any other appropriate technique, the percentage male hybrids and their culture potential in floating bamboo grow-out cages. In addition, Lake Kainji (suggested to be a source of undisturbed populations of tilapias) should be jealously protected so that the purity of its tilapia genetic resources are not contaminated or destroyed by ill-considered introduction and transfers.

(e) An inventory of available waste waters

in Nigeria and their adequacy for fish production using cages should be carried out in order to formulate a strategy for a national integrated waste water management and utilization in aquaculture.

(f) More research should be carried out on the components of what constitute the "hard ware" of the cage culture system (i.e. the floats, raft, net-hapa or net-cage, the anchor line etc) in order to increase the possibility of locally sourcing the materials for durability, efficiency and economics.

(g) Since every State in the Federation is blessed with vast water bodies, fish farming in cages is highly recommended to all Local Governments for use in the suitable sites of these water bodies. For effective and efficient grass root participation, the Community Based Implementation Strategy (CBIS) as favoured by

DFRRI is recommended to be practised by small-scale fishermen farmers grouped into Co0operative Societies, Farmers' Association or Community Development Associations (CDAs) in the national commercial cage culture project. At an estimated annual fish production of 14.4 tons per 4 modules of grow-out cages (i.e. for one Co-operative group, refer to Chapter 9), 34,722 CDAs (about 6J per Local Government Area) or any other Appropriate groups spread all over the water bodies in the country will be involved to produce [illegible] tons of fish using the 4-module small scale CBIS approach. Interested medium and large scale producers can also benefit by using increased number of modules (even up to 100 or more per medium or large scale group).

(h) The fish cage culture technology so far packaged (even though needs further

development) is highly recommended to governmental institutions, non-governmental organisations, organized private sector, banks and other financial institutions, Fish Farmers' Associations, Co-operative Societies, Community Development Associations and individuals interested in fish farming, as a practical, cheaper and efficient alternative to increasing fish production from the abundant existing bodies of water in the country.

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Appendix 1 Average weight (g) at different periods of the mixed fish species stocked in floating cages at Shagunu Bay, Lake Kainji

	PERIOD (DAYS)					
	1	30	60	90	120	150
C. citharus	54.0	156.0	253.5	358.5	458.7	550.0
O. niloticus	50.0	125.0	203.9	287.6	371.6	475.0
C. gariepinus	135.0	228.6	323.7	413.1	509.1	627.0
S. galilaeus	30.0	83.7	140.7	203.7	266.4	335.0
H. bidorsalis	41.8	53.5	65.8	78.4	90.7	110.0
T. zillii	14.3	25.7	38.6	50.9	62.3	77.3
A. dentex	60.0	66.9	74.7	82.2	90.0	97.5
D. rostratus	20.0	49.7	79.7	110.0	141.5	173.0
L. niloticus*	30.0	-	-	-	-	-

* All dead by day 14 of the culture period

Appendix 2 Summary of results (range) for feeding experiments under sections 5.2.1 to 5.2.5

Expt. Code	Feeding Details	Mean Wt/Fish (g)		Mean growth rate (g/d)	Feed Conv. rate	Total Fish Production (kg/m³)
		Initial	Final			
NURSERY 5.2.1	Brewer's waste, Rice bran, Corn bran singly (at 20% of fish biomass)	0.33 to 0.40	1.10 to 1.60	0.0167 to 0.0302	6.53 to 9.12	-
Remarks	Corn bran best (mean)		1.60	0.0302	6.53	-
5.2.2	Combination of corn bran, rice bran and brewer's waste (at 20% of fish biomass)	0.039 to 0.046	0.93 to 1.26	0.021 to 0.029	4.38 to 5.67	-
Remarks	Corn bran + rice bran in ratio 1:1 best (mean)		1.26	0.029	4.38	-
5.2.3	Combination of corn bran, rice bran, brewer's waste, fish meal and premix (at 20% fish biomass)	0.05 to 0.10	3.68 to 5.01	0.0865 to 0.1175	1.13 to 1.29	-
Remarks	Corn bran + Fish meal + Premix best (mean)		5.01	0.1175	1.13	-
GROW-OUT 5.2.4	10%, 25% and 50% blood meal in feeds (at 10 - 3% fish biomass)	3.3 to 3.8	20.0 to 39.1	0.27 to 0.39	1.36 to 2.17	1.993 to 3.910
Remarks	10% blood meal in feed best (mean)		39.1	0.39	1.36	3.910
5.2.5	Commercial feed; blood meal, fish meal and groundnut cake in feed (at 5% fish biomass)	19.0 to 21.0	64.9 to 113.8	0.37 to 0.79	1.12 to 1.86	2.041 to 3.869
Remarks	Groundnut cake in feed best (mean)		113.8	0.79	1.12	3.869

Appendix 3 Mean weight (g) at different sampling periods for Tilapia sp stocked in cages at different densities for 365 days culture period at Kigera III Reservoir, New Bussa

	PERIOD (DAYS)												
	1	30	60	90	120	150	180	210	240	270	300	330	365
I 25/m³	5.3	12.8	20.9	29.3	38.6	47.9	57.2	67.1	76.1	86.6	96.8	112.8	127.8
II 50/m³	6.7	12.7	21.7	28.6	35.5	42.1	49.3	55.3	61.0	66.4	72.7	79.6	87.3
III 75/m³	5.2	10.0	14.8	20.2	25.6	31.6	37.3	42.7	48.4	53.8	59.8	67.5	75.2
IV 100/m³	4.6	8.8	13.0	17.8	22.3	27.1	31.6	36.4	40.6	45.4	49.9	55.6	63.9

Appendix 4 Pooled summary (Tables 7.3 and 7.4) of fry production of Oreochromis niloticus (ORN) x Sarotherodon galilaeus (SAG) hybridization experiments

Treatment	Sex Ratio (M:F)	No. of Fry produced	Average No. of fry/spawning	No. of Fry/ female	Spawning frequency/ month
I All ORN	1:3	1352(6)*	225	150	1.9
		2011(5)	402	233	1.7
	Mean	a1682(5.5)	314a	192a	1.8a
II All SAG	1:3	325(3)	108	36	0.9
		47(1)	47	5	0.3
	Mean	b186(2)	78b	20.5b	0.6b
III Male ORN, Female SAG	1:3	52(2)	26	6	0.6
		217(2)	109	24	0.6
	Mean	b134(2)	67.5b	15b	0.6b
IV Male SAG, Female ORN	1:3	777(5)	155	86	1.5
		895(5)	179	99	1.7
	Mean	b836(5)	167ab	93b	1.6a

* Total number of spawnings in parenthesis

Means in a column with the same superscript are not significantly different at 5% DMRT

Appendix 5 Range and mean of the physico-chemical parameters of the water during the hybridization and fry rearing experiments.

Parameters	Range	Mean
Water temperature (°C)	24.0 - 34.0	28.0
pH	7.2 - 8.5	7.6
Dissolved Oxygen (mg/l)	4.5 - 6.0	5.5
Transparency (m)	0.50 - 0.70	0.55
Primary productivity (g C/m^2/day)	0.34 - 4.35	1.35
Conductivity (µmhos/cm)	245 - 260	254

Appendix 6 Pooled data (i.e. Tables 8.2 and 8.3) from the results on S. galilaeus stocking densities experiments in floating cages in a sewage pond for 150 days culture period

Treatment	Average Wt (g) Initial	Final	Ave. Daily Wt. Gain (g/d)	Survival (%)	Production (kg/m³)
I	13.5	48.0	0.23	80.0	0.768
20/m³	10.0	52.0	0.28	70.0	0.728
	11.8	50.0[a]	0.26[a]	75.0[a]	0.748[a]
II	9.8	32.3	0.15	60.0	0.775
40/m³	10.0	37.0	0.18	92.5	1.369
	9.9	34.7[b]	0.17[b]	76.3	1.072[b]
III	8.3	32.3	0.16	77.0	1.492
60/m³	10.0	23.5	0.09	83.0	1.170
	9.2	27.9[b]	0.13[b]	80.0[a]	1.331[b]
IV	11.9	22.4	0.07	83.8	1.502
80/m³	10.0	31.0	0.14	67.0	.662
	11.0	26.7[b]	0.11[b]	75.4[a]	1.582[b]
V	10.2	22.2	0.08	40.0	1.066
120/m³	10.8	27.3	0.11	85.0	2.785
	10.5	24.8[b]	0.10[b]	62.5[a]	1.926[b]
VI	10.6	25.6	0.10	90.0	3.686
160/m³	10.6	24.1	0.09	93.8	3.617
	10.6	24.9[b]	0.10[b]	91.9[a]	3.652[b]

Means in a column with the same superscripts are not significantly different at 5% DMRT

Appendix 7 Sources and life span of materials for Cage Fish Farming in Nigeria.

Materials	Life Span (Yrs)	Sources
1. Knottted nylon netting	3 - 5	a) Nigerian Fishing Net Industries Ltd, Plot F, Kirikiri Industrial Estates, Amuwo, Festac Town, Lagos.
		b) Stretch Fibres (Nig) Ltd, Plot 118 Trans Amadi Industrial Layout, Port Harcourt.
		c) Fishing Nets Dealers Shops at Aba, Kano, Lagos, Port Harcourt etc.
2. Hapa netting, Kuralon twines, nylon mounting twines, anchor line.	3 - 5	Fishing nets and ropes dealers shops at Aba, Kano, Lagos, Port Harcourt etc.
3. (i) Plastic floats - factory sealed (100-1 capacity): black	5 +	a) Tate and Lyle (KWALIPIPE) Ajase Ipo Road (near Matchco) Ilorin
green	1 - 3	
white	< 1	
(ii) Second hand plastic drums	1 - 5 +	b) Dealers in second hand plastic and metal drums especially at Moloney Bridge St, Lagos Island
(iii) Second hand metal drums: unpainted	< 1	
painted	2 - 3	

Appendix 7 (contd.)

Materials	Life Span (Yrs)	Sources
4. Bamboo poles:		
(i) in direct contact with water (i.e. also serving as float)	< 1	Major towns and villages especially in the Southern and Middle belt Areas of Nigeria.
(ii) not in contact with water (i.e. buoyed with floats)	3 +	
5. Fish feeds		a) Livestock Feeds Ltd, 1 Henry Carr St, Industrial Estate, Ikeja. b) Other Livestock Feeds Ltd., manufacturing locations at: i) 12 Industrial Layout, Aba, Imo State ii) Sapele Rd, Benin-City, Edo State. iii) Ibrahim Waziri Crescent, Kaduna Kaduna State. c) National Institute for Freshwater Fisheries Research, New Bussa, Niger State. d) Nigerian Institute for Oceanography and Marine Research, Point Rd, Victoria Island, Lagos
6. 3mm diameter iron rods and nails	3 +	Nigerian Wire Industries Ltd, 4 Henry Carr St., Industrial Estate, Ikeja Lagos.