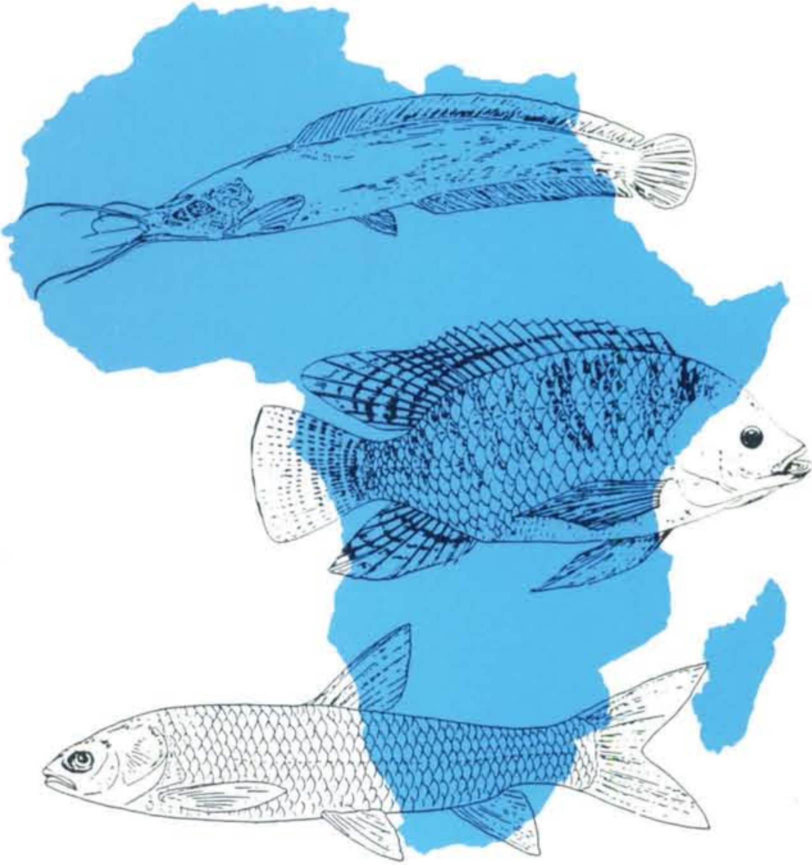
Village Level Aquaculture Development in Africa



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Village Level Aquaculture Development in Africa

Proceedings of the
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on Village Level Aquaculture
Development in Africa.
Freetown, Sierra Leone.
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Foreword

Commonwealth Ministers of Agriculture, Food and Rural Development have consistently called for greater attention towards the development of aquaculture as a means of augmenting marine fisheries production and as a source of protein, especially in areas of poor accessibility.

The Commonwealth Consultative Workshop on Village Level Aquaculture Development in Africa held in Freetown, Sierra Leone, 14-20 February 1985, set out to address some of the problems encountered and to identify solutions in mitigating the slow progress of village level aquaculture in Africa.

Some of the constraints which face aquaculture development include the inadequate provision of resources for technology development and transfer, the slow adaptation to existing socio-economic conditions, and the slow rates of adoption and application of new technologies due to inadequate support services for extension personnel. These services include the provision of fish farming gear, transportation, and credit facilities to farmers.

The consultation was held with the support and co-operation of the Government of Sierra Leone and that of the Food and Agriculture Organisation's (FAO) Aquaculture Development and Co-ordination Programme, the British Overseas Development Administration (ODA) and private consultants.

The Commonwealth Secretariat extends its gratitude to the Government of Sierra Leone for hosting the consultation and for the tireless effort of the Ministry of Agriculture and Natural Resources, especially the Acting Chief Fisheries Officer and his members of staff for all of their support without which the programme would not have been a success.

Thanks are also due to all participants whose first-hand knowledge of events in the field gave insight into the constraints field workers are faced with. Special thanks are due to all those individuals who contributed excellent papers and discussion topics, which formed the basis of the consultation.

These papers have been edited by Ms. H. R. King and Dr. K. H. Ibrahim, to whom I am grateful.

J. K. Muthama
Director
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Introduction

The practice of aquaculture in Africa has ancient origins yet, the introduction of more conventional fish farming systems is encumbered by an array of difficulties. It is recognised that these difficulties can be overcome given a redirection of approaches.

One of the traditional areas of development assistance in aquaculture has been training. This no doubt needs to continue. The Commonwealth Secretariat, for some time now, has consistently provided such opportunities for trainees from Commonwealth countries in Africa and Asia. However, other very essential aspects need to be included in development assistance if effective and sustained development is to materialise. With this in view, the consultation was organised with the following objectives:

> To examine the technical, and socio-economic factors that inhibit the successful introduction of aquaculture to rural communities in Africa.
>
> To identify ways and means of overcoming these problems at governmental and grassroot levels.
>
> To identify technical needs, including training.
>
> To heighten awareness amongst extensionists on the potentials of aquaculture development.

From the discussion of papers presented and the first hand experiences of participants, it became clear that the issue was a complex one requiring the concerted effort of governments and development assistance agencies. These discussions and ensuing conclusions were crystallized in the Resolution overleaf. Amongst the major problems identified were the following four categories, further amplified in the Resolution:

1. *Socio-economics*: an inadequate understanding of the target communities to which aquaculture was introduced.

2. *Poor Extension Services*: reflected in inadequately trained and insufficient numbers of extensionists, in addition to inefficient support services, including transportation and poor back-up research facilities.

3. *Fish nutrition*: the lack of simple and cheap nutritional systems for the improvement of pond productivity.

4. *Project Monitoring and evaluation*: inadequate or non-existent monitoring and evaluation of projects; necessary prerequisites for project survival.

The enthusiasm and dedication of participants was encouraging, in the light of the obvious difficulties many aquaculture services are faced with. The Resolution adopted by participants pinpoints the most urgent areas in which asistance is required. It is the hope that these recommendations will contribute towards the realisation of village aquaculture development in Africa.

Resolution on Village Aquaculture Development in Africa

The participants of the Commonwealth Consultative Workshop on Village Aquaculture Development in Africa, assembled in Freetown, Sierra Leone from 14 - 20 February, 1985. After discussion and review of the biological, technical and socio-economic factors inhibiting successful aquaculture schemes in Africa, recognised the fact that some of these problems could be resolved at grass-roots level with sufficient governmental support and through the assistance given by bilateral and multilateral donor agencies.

It was also felt that there was a general need to make planners and decision makers aware of the immense potential of village aquaculture in increasing food production, employment and social benefits.

The participants thanked the Commonwealth Secretariat for the opportunity to meet and discuss problems relating to aquaculture development in Africa and recommended the following areas in which the Secretariat could assist.

1. One of the weakest links in promoting aquaculture development in Africa is in the area of extension. The personnel of extension units are insufficient and inadequately trained, and where available, their insufficient numbers do not permit adequate coverage of their duty areas. This is coupled with the inadequate and inefficient support services at their disposal, including transportation.

   (a) It was therefore recommended that the funding agencies undertake the organisation of training workshops for middle level extension officers of not less than two weeks duration, in individual Commonwealth countries in Africa, employing consultants/experts from neighbouring African countries or outside Africa, as appropriate, for the purpose of conducting such workshops.

   (b) The FAO/UNDP/NIOMR African Regional Aquaculture Centre (ARAC) at Port Harcourt, Nigeria was created to train senior aquaculture officers in Africa. Participants expressed gratitude to the Commonwealth Secretariat, FAO, ADB and other funding agencies for their support in funding trainees to ARAC. However many countries were not able to take full advantage of this opportunity due to financial difficulties. It was therefore recommended that the Commonwealth Secretariat formalise arrangements with FAO to make more scholarships available to ARAC so that Commonwealth countries in Africa could participate annually in the ARAC training scheme. Other donor agencies were also urged to provide similar support to other African countries.

It was also considered essential that, in addition to formal training, provision be made for and encouragement given by international agencies, to the idea of exchange visits for scientists and aquaculture extensionists to African and Asian countries with aquaculture systems and traditions.

2. It was felt necessary to have a survey and assessment of existing demonstration fish farms in various countries and where necessary initiate reactivation programmes and/or the construction of new ones.

3. Since all participating countries expressed inadequacy in the supply of fish seed it was recommended that immediate and intensive programmes on production of quality fish seed be initiated through available modern techniques. Construction of hatcheries in different regions was considered essential.

4. While considering the socio-economic conditions of the village level aquaculturist, it became evident that he was seriously handicapped with an inadequacy of funds and resources. It was therefore felt necessary to take suitable measures for channelling the much needed loans and inputs through already existing channels, to be at par with similar arrangements for village agriculturists, on easy terms.

5. The lack of simple and cheap nutritional systems for aquaculture, particularly in rural areas, was felt by all participants. It was therefore recommended that the possibility be explored to adopt already existing systems for improving pond productivity through simple and integrated practices.

6. The necessity of conducting applied aquaculture research on regional and national levels was considered essential. However, the general opinion was to restrict the same to a limited number of proven species.

7. Lack of exchange of information on aquaculture development and research among various African countries was considered a serious handicap and to improve this, exchange of technical reports among the countries was recommended. In addition to this, international organisations should consider providing assistance in setting up an information exchange forum.

8. In order to increase participation in aquaculture production, schools and other institutions should be encouraged to take up aquaculture programmes, or strengthen existing ones. National governments and donor agencies were urged to support this effort in order to increase awareness in the potentials of aquaculture development.

9. A number of aquaculture project failures in Africa are due to an inadequate knowledge of socio-economic conditions. Fisheries institutions and programmes were therefore urged to train and to include sociologists and economists in their projects and in the fisheries staff structure of national governments.

10. Project monitoring and evaluation, post implementation, was considered a vital aspect for the survival of any project. The inadequate levels of monitoring and evaluation of village aquaculture projects was recognised as a major shortcoming. It was therefore recommended that sound systems of project monitoring and evaluation be built into aquaculture project documents from their inception.

AQUACULTURE PRACTICES IN AFRICA

SYSTEMS IN USE AND SPECIES CULTIVATED

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1. Introduction

The status of aquaculture development in Africa has been the subject of considerable debate in recent years for despite a nutritional need to increase fish production, fish farming has far from achieved predicted goals. Perhaps the first quantified report of fish farming activities in Africa is that by Meschkat (1967) presented during the 1966 'FAO World Symposium on Warmwater Pond Fish Culture'. This was followed in 1975 by the first Regional Workshop on aquaculture planning in Africa (FAO 1975) and Symposium on Aquaculture in in Africa (FAO 1976) both held in Ghana. These were followed by other meetings (CIFA 1980, Coche 1983), FAO Technical Conference on Aquaculture, Kyoto (Pillay and Dill, 1976) and World Conference on Aquaculture, Venice (Pillay 1981). Balarin and Hatton (1979) reviewed the situation but with special reference to the tilapia while (CIFA, 1974) list other species of importance in Africa and FAO (1982a) describe research centres and Chakroff (1982) reviews extension services.

More recently the situation has been discussed at the 'FAO World Fisheries Conference, Rome' and during 'Aquacoltura '84, Verona'. Although the proceedings have yet to be published, Anon (1984) makes reference to the latter. The material from these meetings was not available to include in this study. Presented here therefore is a review of those reports already mentioned as well as available major country status reports published since 1980. These include works on Zambia (FAO, 1980); Ivory Coast (Vincke, 1982); Mozambique (FAO, 1982b); Rwanda (Schmidt and Vincke, 1981); Central African Republique (Blessich *et al*, 1983); Malawi (Cross *et al*, 1983); Tunisia (FAO, 1983); Congo (Balarin, 1983); Egypt (Sodek, 1984) and a current FAO 12 country review by Balarin (1984a-g) and Balarin (1985, h-l).

2. History of Fish Culture in Africa

Although carp culture, first initiated in China, is believed to be the forerunner of modern day aquaculture, tilapia keeping in ponds in Egypt around 2500 BC, nearly 1000 years before, heralded the start of the concept of fish farming. The only remnant of an ancient traditional fish farming technique is the Howash farms in the Nile Delta in Egypt which by virtue of their extensive area (=30 450ha, Sadek, 1984 and 48 845ha, Ardill, 1982) suggest a long standing practice. Other apparently indigenous traditional fish culture practices which have evolved in Africa include the brush-parks or 'acadja' system of Benin (Welcomme, 1971), Ghana and Madagascar (Ardill, 1982) the fish holes of 'Whedos' of Benin and Cameroon (Welcomme, 1976); and the 'Barachois' of Mauritius (Ardill, 1982). These systems are unique to Africa. No documented evidence however is available of their early development history but reports acknowledge the existence of such fish culture systems over the last two centuries.

Fish culture proper was therefore reintroduced into Africa during the colonial period with perhaps one of the first developments taking place over one hundred years ago (Safriel and Bruton, 1984). For reasons of familiarity and preference, the Europeans favoured exotic fish (e.g. trout, carp and black bass). Initially therefore between 1910 - 1960 large numbers of exotic fish were introduced into African waters. The main emphasis however was rearing and stocking of sport fisheries. It was soon apparent that there was scope to increase fish production through reservoir stocking as a ration fishery and later through classical pond culture. Perhaps the first scientifically orientated approach to farming fish for food was initiated in tilapia culture in Kenya in 1924. Balarin and Hatton (1979) describe this early progress, but it was not until after the Second World War that fish farming was extensively introduced into rural communities with the establishment of demonstration experimental farms and an active extension agency. By 1960, Anon (1984) describes over 300,000 ponds operational in 20 African countries, most were rearing tilapia. From then on interest would appear to have rapidly deteriorated except where considerable Government support was provided. Farmers possibly became discouraged by the effort required for little return due to stunting in ponds of the favoured tilapia. An absence of technical understanding to curb this as well as biological problems in breeding of a suitable alternative such as Clarias, Carps or any other indigenous species led to an abandonment of ponds.

Recent innovations in warmwater fish farming technology and realisation of the importance of fish production in rural communities had seen renewed efforts on the part of Governments and foreign aid agencies such that 20-30% of the original pond developments have now been reactivated.

3. The Status of Aquaculture in Africa

For the purposes of this study 54 countries and outlying islands of Africa were considered. Available data on statistics from published and unpublished works generally indicate that the information was scant and no reports were available for Cape Verde, Comoros, Equatorial Guinea, Guinea Bissau, Namibia, Sao Tome, Zaire and Western Sahara.

3.1 Aquaculture Statistics

Coche (1983) considers that statistics are both contradictory and often lacking such that no accurate estimate was possible. Production in 1981 was considered not to exceed 10,000t/yr contributing less than 0.1% to World aquaculture given as 8.7 million tonnes. CIFA (1980) refers to 1975 statistics, an estimated 107, 400t/yr about 1.8% of World production, while FAO (1975) lists over 30,000t/yr from only nine African states. Statistics remain confused because of the diverse nature of rural pond farming, absence of an organised aquaculture census and an uncertainty of the definition between fisheries management, semi-aquaculture activities and capture fisheries. For the purposes of this text the following definition is considered.

Aquaculture is defined as any increase in production from a man-made or modified area through some form of human intervention beyond that of merely harvesting the fish.

A composite picture of reported statistics is therefore presented in Table 1. The gaps and shortcomings of such a statistic emphasise the need for the enstatement of an enumeration system as established for fisheries, a feature likely to be vital in future fish farm development planning. The data presented suggests over 321,000 ponds as having been established, representing between 23,000-79,000 ha. The yield falls between 6950-144,400t/yr but is more than likely more closely approximated by the lower value.

3.2 Development Status

Aquaculture development in Africa falls into two broad categories varying according to organisational patterns, level of sophistication and intensity of operation. There are however a number of intermediate levels but the definitions adopted here are after Pillay (1975):

(a) *Small Scale Rural Aquaculture* characteristic of rural developments either by individual subsistence farmers, artisanal, village or community groups employing relatively unsophisticated techniques for the purpose of additional food production often integrated with other farming systems. Practised as a sole or part-time occupation, often dependent upon public sector involvement either for funding or support services, production units are small and yields low.

(b) *Large Scale Aquaculture Industry* generally developed as private sector investment or government corporate activity, involving large capital outlay, centralised management and a certain degree of vertical integration, the dominant objective is return on investment i.e. commercial activity. Development involves intricate feasibility study for correct system, species and site choice and is dependent upon inputs to maximise yields efficiency, often on a large scale.

The first type applies to the theme of this paper but the second is considered in the light of Balarin (1984h) and in terms of its future role in food production.

Initial emphasis in aquaculture in Africa was perhaps commercial enterprises for up-market fish such as trout or the rearing of black bass for sale to farmers for dam stocking, but the biggest development was into rural aquaculture. Over 37 of the countries considered list small scale developments. Of these by far the most extensive activities are in Zaire, Madagascar, Kenya, Central African Republic, Egypt, Cameroon and the Congo where over 85.6% of ponds were recorded (Table 1), 38% in Zaire alone. No statistics however are known for Nigeria which records up to 75,000t/yr production (CIFA, 1980) although conflicting reports suggest a low 127t/yr. (Bell and Canterberry, 1976). Rural aquaculture currently accounts for most of the aquaculture production in Africa generally concerning subsistence farmers using small 100-500m2 ponds utilising domestic wastes, composts, manures or occasional cottage agro-industry wastes as supplements.

Large scale industrial aquaculture does not appear to have developed to any large extent perhaps for economic reasons due to a past history of fish as the lowest priced animal protein. In addition to projects listed by Coche (1983) there are about 10-15 examples of public or private commercial enterprises, 13-20 pilot projects not yet demonstrated as economically viable and a number of development projects still at the planning stage. In all, 23 countries report large scale activities. Of these few are actually producing. These are notably the tilapia farms in Ivory Coast, Kenya, Malawi, Nigeria and Egypt, trout farms in Kenya and Zimbabwe, macrobrachium projects in Mauritius and Zimbabwe and oyster farms in Senegal. Perhaps some of the largest scale projects are planned for Egypt (three farms of 1000ha), Angola (500t), Lesotho (350ha), Upper Volta (450t), Libya (700t), Madagascar (200ha) and Kenya (various).

Most of the countries in Africa report freshwater culture practices. Mariculture activities have only a relatively recent history and there is a trend toward making use of brackish waters. Despite over 30 million hectares of potential coastal region suitable for cultivation (Bell and Canterberry, 1976), Africa has probably not ventured into marine farming until recently for lack of an understanding of the biology of indigenous marine species and precedence in planning priority to first exploit the fishery resource. Coastal aquaculture, mainly in lagoons, is now being considered although brackish water Howash, Acadjas and Barachois systems have a long history of use (Ardill, 1982).

3.3 Aquaculture Strategy Objectives

The development of aquaculture has generally been for the purpose of enhancing food production as discussed above, but there are a number of other applications which have found use in Africa. Briefly the objectives of aquaculture can be classified as:

(a) Production of fish for human consumption either local or for export.

(b) Improvement of natural stocks or introduction of fish into new waters such as man-made reservoirs through artificial recruitment or transportation.

(c) Production of fish for fishery stocking.

(d) Production of a forage fish for rearing of a more valuable species.

(e) Production of bait for commercial or sport fishing.

(f) Production of ornamental or aquarium fish.

(g) Recycling of organic wastes, such as in sewage oxidation ponds.

(h) Rearing of select fish for stocking waterways for aquatic weed control as well as control of vectors of such diseases as malaria or bilharzia.

(i) Production of trash fish as a constituent of animal feeds.

Each of the above objectives could apply at village level but developments have decidedly been toward the production of food fish. Governments have concerned themselves with items b, g and h but whereas private enterprise has catered for c, d, f and to a limited extent, i, developments have been small. The limitations of this text will therefore be mainly toward food production but systems again can fall under one of two classifications:

- Seed production
- Table fish production

In rural enterprises there are very few specialised seed production farms generally this is a service provided by Government or from farmer to farmer. Government therefore by definition (Section 3.2a) provides most of the support services. Extensive research, either government or foreign aid assisted, has taken place in Egypt, Ivory Coast, Nigeria, Central African Republic and Zambia. Kenya and Zimbabwe register considerable research input from the private sector as well as having incountry commercial consulting firms to assist in technological transfer. The status of national extension programmes also indicates Cameroon and the Central African Republic as having a well developed service. In all 36 countries provide some form of extension training. There exists in Port Harcourt, Nigeria, a bilingual training institution for senior aquaculture staff at the 'African Regional Aquaculture Centre'. Other countries such as Central Africa, Congo, Ivory Coast, Madagascar and Kenya also provide training under an FAO/UNDP framework for small scale aquaculture development.

4. Aquaculture Systems in Africa

The fish farming techniques employed can be placed into two distinctive groups. These are:

(a) *Traditional Methods*: certain systems are believed to have an origin in Africa and are unique to the countries concerned having been practised for as long as anyone can remember. These are the Howash of Egypt, Acadjas and Whedos of Benin and Barachois of Mauritius (Table 2).

(b) *Conventional Methods*: reservoir or rice paddy stocking, ponds, cages, pens, tanks and raceways are all modern techniques, the concepts of which have been transferred from the developed nations and applied under African conditions. Introduction has been during the last 50 years and is now widespread (Table 3).

The distribution and level of application of each system type is summarised in Table 3. Detailed discussions of a technical nature are beyond the scope of this text but a brief description of each is provided emphasising the possible future application.

4.1 Degree of Intensification

The systems used in Africa fall into a number of categories of intensity of production which can be defined as :

(a) *Semi-aquaculture or 'ranching'*: fish are reared and either released into a natural water body or man-made reservoir with no further input other than harvesting. In addition certain structures such as 'brush-parks' may be employed to increase production but reproduction is uncontrolled, feeding negligible with perhaps occasional manuring. This operation approaches 'rangeland management' with yields generally low, up to 1.5t/ha/yr and applies to traditional systems, dams, ponds and rice paddy stocking.

(b) *Extensive Aquaculture*: analogous to 'pasture agriculture', the practice employs man-made units, generally rice fields or ponds, where production is dependent upon natural or enhanced natural productivity. Manure or fertiliser application or integration with livestock can be used to enhance primary production, but feeding if practised is supplemental. The limit to production is the level at which natural processes can provide food or oxygen needs and yields can attain a maximum of 5t/ha/yr. This specifically applies to pond systems.

(c) *Intensive Aquaculture or 'Feedlot'* is almost exclusively dependent on pond fertiliser or artificial feeding levels. Some form of aeration or flow is necessary for oxygen needs and system cleaning and careful attention is needed to system design. A certain infrastructure is required involving high capital investment, management is complex and the high energy requirement restrict such practices to commercial operations with possible yields as high as 2000t/ha/yr. Cages, tanks and raceways fall under this category.

The last category applies to system types where high density stocking necessitates feeding (Table 3) and represents a very recent development trend in African aquaculture. In the past, feedlot practices were limited to trout and then only on a small scale. Present day price increases of food fish due to limited fishery supply have meant that such intensive practices are now becoming more economically viable justifying the expensive feed costs. Although not strictly practised at the village level as are the other two categories, intensive systems hold potential in the future to develop as community investment projects. Feedlot practices are included here therefore as a means whereby levels of production could be increased at a rate likely to satisfy demand.

4.2 Traditional Aquaculture Systems

The systems listed in Table 2 each have a unique prerequisite set of site requirements and therefore are limited in their application but are to be considered as a possible alternative development for fishing villages who fish an already overexploited fishery.

4.2.1 Lagoon Stocking/Barachois

As described by Ardill (1982) the system of Barachois is found only in Mauritius where the fringing coral barrier reef encloses a fairly sheltered and shallow lagoon. Coastal inlets in such lagoons are cut off by stone walls often fitted with screened gates for waterexchange. Fingerlings of mullet, *Siganus sp.* as well as any other fish fry caught by chance are collected from the lagoon and stocked in the Barachois at variable rates, generally approaching 1000/ha. Oyster farming may be included. Stocking and harvesting are an annual exercise and although low, yields are double the natural productivity of the lagoon.

The system is capital intensive but of long depreciation and low labour cost however as management has no control, production is low and tidal exchange precludes fertilising to increase yields. Predators and poaching account for heavy losses and legislation now prohibits any further such developments.

Whereas Barachois have found use in Mauritius, it is likely that they may have application in other coastal lagoons around Africa or in freshwater floodplains similar to the 'Modulas' in South America (Welcomme, 1976). Currently similar lagoons either artificially or naturally sealed are stocked and fished; practices common in Egypt, Ghana, Madagascar and Tunisia. Bell and Canterberry (1976) estimate Africa has 30 million hectares of suitable coastline for mariculture. Were 10% put to use and at a low 100kg/ha/yr, the potential is 300,000t/yr.

4.2.2 Fish Holes

Welcomme (1976) describes a series of artificial ponds or river channels which have been employed in Benin with similar systems found in Cameroon (Balarin 1984f) and Togo (Balarin, 1984d).

Generally termed 'Whedos' or 'Houedo' in Benin, production is proportionate to size of unit and yields of between 1.5-2.1t/ha/yr were recorded. Species composition however varied with size for excessive vegetation growth in small units created deoxygenated conditions favouring air breathing fish. *Clarias* are therefore common as are *Paraphiocephalus* spp in ponds below 500m^2. *Heterotis niloticus* was found in larger units and over 5000m ^{u}nits were characterised by Mormyrids and *Lates* sp.

A hybrid between 'Whedos' and 'Acadjas' (see section 4.2.4) termed 'Ahlos' is also described for Benin, where the trenches are filled with branches to increase production. The success of both methods depend upon a drain-in principle to concentrate fish as flood waters recede. The fishery represents a large scale infrastructure integrated into the traditional life of people living in the Oueme Valley, Benin. The technique is open to improvement by more effective management through artificial stocking and feeding and has a wide application elsewhere in swamp fisheries. Africa has over 12.0 million hectares of floodplain. Were it possible that only 1% of this area could develop a whedo system at yields of 1t/ha then 120,000t/yr could be produced.

4.2.3 Howash

This can be considered as a hybrid between the principle of 'Barachois' and 'Whedos'. Howash systems are unique to the Nile delta in Egypt where the flat topography permit the establishment of shallow ponds bounded by earthen dykes. Three types occur. (Tang, 1977):

(a) *Coastal*: distributed on the seaward slopes of the land between the Mediterranean sea and coastal lakes, such howash are filled by tidal action and have a salinity of 10 - 25ppt.

(b) *Lakeshore*: distributed around Lake Manzala and Burullous, of low salinity (0 - 5ppt) these howash are constructed on the lakeward slope and filled by the discharge of the irrigation drainage.

(c) *Lakewater*: actually built within the lakes to a depth of 2m but generally smaller than the other types and salinity of 0 - 10ppt.

The principle of howash systems is also employed in south-east Asia for milkfish farming but is not described elsewhere in Africa. Although present use of the howash in Egypt is currently controversial due to loss of potential irrigation water and interference with fisheries, the scope however for such developments in Africa is enormous for employment in low lying areas.

4.2.4 Brush-park (Acadja)

Recently reviewed in Balarin (1984e) there are eight different types of brush-parks as listed in Table 2 as described by Welcomme (1971) subdivided into two basic groups:

Akadjavi – round or circular in shape with hard wood outer ring and branch piles inside.

Ava - Generally larger, rectangular in shape.

Customarily 12 - 16 branches/m2 are used but production varies as a factor of density of branches:

$$\text{Log } P = 0.165d - 1.285$$

where: P = Yield in t/ha/yr

d = density of branches (n/m2)

About 30 - 60t/ha of dry wood is needed with an annual replacement rate of 30 - 75% requiring 75 m.d/ha which represents a large input and requirement for wood. Resultant deforestation has led to a decline in this practice such that new enclosure techniques are now being tested in Benin by an EDF funded project.

Generally *Sarotherodon melanotheron*, and *Chrysichthys* sp make up 60 - 96% of catches in Benin; fish are small 10 - 20cm and caught by net encirclement of the acadja and removal of branches. Production is calculated:

$$P = 0.957e\ 0.179t$$

where: P = Yield t/ha/yr

t = time in months since construction

4.3 Conventional Aquaculture System

Systems described in Table 3, although of a wider application than traditional methods, have not developed to the same extent perhaps due to an initial poor technological understanding.

4.3.1 Lake and River Fishery

Enhancement of natural production is possible by the introduction of fish species to fill a vacant niche. Successful examples are Nile Perch (*Lates niloticus*) stocked in Lake Kyoga and Lake Victoria and *Limnothrissa* sp in Lake Kariba. Although not strictly an aquaculture practice it is nevertheless a management tool also used in the control of aquatic weeds, malaria or bilharzia.

4.3.2 Retention Dams

Most parts of Africa are arid and dams have been constructed for water storage during the dry season for use as domestic or livestock water, by industry or mainly for irrigation. Such dams often lack a natural complement of fish and artificial stocking is necessary. Generally in order to create a balanced ecosystem a polyculture is preferred. Production is low but can be increased to 1.5t/ha/yr by regular stocking and manure application. Recently reviewed by Balarin (1984i), Africa has 6 million hectares under irrigation and potentially each hectare irrigated from a water reservoir or night storage dam could yield between 20 - 200kg/yr of fish. Assuming that only 25% of irrigated hectarage in Africa has a storage dam then a yield of 30 - 300 thousand tonnes per year is possible.

4.3.3 Rizipisciculture

Rice and fish production in the same paddy field has been tested in 28 countries but the greatest development success has been in Madagascar (Vincke, 1976). Rice paddies normally flooded to a depth of 10 - 24cm for 90 - 120 days are stocked with fry of 1 - 3cm one week after transplanting the rice. Tilapia and carps are preferred and either harvested with the rice or the fields reflooded and used as ponds yielding up to 2.25t/ha/yr with a potential 5 - 15% increase in rice. Integration provides weed, bilharzia and malaria control as well as reducing algal blooms and provides fertiliser through fish feaces and tillage due to the activity of the fish. Assuming 10% of irrigated land were rice, then at a low 300kg/ha/yr, Africa could realise an additional 180,000/yr fish production.

4.3.4 Pond Culture

Pond culture is perhaps the most widespread practice in Africa having been introduced into over 40 countries. Between 270 - 321 thousand ponds (Table 1) have been built of which possibly less than 25% are currently active. The greatest development has been subsistence small scale developments but some semi-commercial activities are recorded. There are four basic approaches to pond farming described in Table 3.

4.3.4.1 Subsistence Pond Culture

Ponds are either excavated, raised dykes or barrage type across streams or below larger reservoirs. Simple water inlet/outlet devices if present are either of bamboo, metal pipe or concrete monks. Pond size varies from 100 - 500m grouped around village or irrigation water sources. Community, family or individually built and owned, ponds are fished mainly for food. Design and layout can be poor, management variable and inputs consist of domestic wastes or composted weeds often placed in pens in the ponds. Yields are low, with production of 100 - 500kg/ha/yr common. With better manure or supplements, productions of 2.5t/ha/yr are reported but are rare generally due to competition between agriculture and livestock for such inputs.

The species most often used is the tilapia or mixed stocks but choice is generally dependent on availability from Government Seed Centres. Tilapia is a hardy species, ideal for these systems but its prolific breeding habits and the absence of any technical inputs to curb reproduction results in a harvest of small fish which has discouraged developments. In cooler areas, carps are now being introduced and other more frequently preferred species are *Clarias* and *Heterotis*, with the use of *Labeo, Lates, Micropterus* and *Hemichromis*, being tested.

The requirement for a supply of seed and some technological know-how necessitates Government support to such projects in the form of extension services. Funds and available trained manpower as well as the required infrastructure for training, research, seed production and transport are the main limiting factors. Although of high potential for integration with small holder irrigation schemes, the low yields often do not economically justify the national cost required to support such developments. However, limited success can provide animal protein production in rural areas where it might be needed. If the 23 - 79 thousand hectares of ponds in Africa were reactivated to give over 1t/ha/yr this would yield between 25,000 - 80,000t/yr.

4.3.4.2 Semi-intensive Pond Culture

This system attempts to make maximum use of natural productivity to provide food and oxygenation without the need for additional energy inputs for aeration. Fry of 5 - 25g are stocked at 10 - 30 thousand per ha in well constructed pond units. To enhance production, fertiliser or manures can be added. These include the following applications in kg/ha/week. Lime (40 - 55), super phosphate (15 - 30), pig manure (560 - 1630), poultry manure (110 - 225) and cattle or horse manure (670). Alternatively, integrated animal-cum-fish husbandry is possible. Animal pens can be built either over the fish pond or on the banks and all liquid and solid wastes are lead into the pond. Yields expressed as t/ha/yr per animal stock rate are: pigs (70 - 100/ha) = 5 - 10, ducks (1000 - 2000/ha) = 4 - 8, chickens (1000 - 1200/ha) = 3.5 - 7 and geese (500 - 800/ha) = 2 - 3. Pond production can be improved by supplementing the natural foods by artificial feeds.

Pond harvest can be intermittent by netting or total drainage with potential yields as high as 5t/ha/yr; however for tilapia 2.5t/ha/yr is more common due to prolific precocious breeding producing smaller fish. Higher yields can be obtained by curbing reproduction (Balarin and Hatton, 1970). Monosex culture can be achieved by feeding fry a male hormone diet containing 30mg/kg methyltestosterone. If administered within the first week after hatching for 45 days, all male fish result. More popular is the use of select species hybrids which tend to yield all male offspring. Predator stocking with *Clarias, M. salmoides, Hemichromis spp* or *Serranochromis spp* can be effective as they prey on and control fry numbers. This polyculture increases yields. Other methods such as hand sexing for monosex, gynogenesis, irradiation, chemical castration or size grading have also been used.

Such semi-intensive practices have found application in Zimbabwe, Zambia, Malawi, Central African Republic, Kenya and Nigeria but are generally at a small scale where there is competition for feeds and fertilisers with traditional livestock and crop use. In Asia this integration is long established to the extent that sewage finds ready use in ponds, a concept considered unethical in Africa. There is however scope in Africa for integrated irrigation, farming of livestock and fish; large projects are planned or underway in Zambia, Nigeria, Kenya, Madagascar and Central African Republic.

4.3.4.3 Intensive Pond Culture

To achieve yields above 5t/ha/yr biological processes need to be assisted. This includes aeration, waste removal and a trend toward an independence of natural foods. Ponds now are of an elaborate design, with reproduction control mechanisms a must; feeds are a pelleted, balanced ration, formulated from basic stockfeed ingredients. In such a regime, feeding in ponds becomes regular, daily at 10% body weight for juveniles (+1g and 1.5%) for adults (+250g). Food conversion ratio of dry feed to fish flesh is nearly 2:1 and yields can, under super-intensive conditions, be as high as 25t/ha/yr (Table 3). To sustain such a fish biomass, aeration, using either paddle wheels, venturi type blowers, permeable plastic tubes or floating impeller units are necessary to provide oxygen.

4.3.5 Cage Culture

If deep, lagoons, irrigation reservoirs, lakes or waterways can support cage culture, net enclosures or pens in the shallows. Cages are a floating collar made of either old oil drums, styrofoam and wood, supporting a bag made of fine mesh, nylon netting. Currents are created by winds for the oxygen needs of the fish. This permits stocking of densities upto 250 fish/m3 of cage. Intensive feeding with a pelleted balanced diet can yield an equivalent of up to 700t/ha/yr. The system is ideal for tilapia as the mesh of the cage floor does not permit successful breeding and is an effective reproduction control mechanism.

Although tested in Egypt, Zimbabwe, Kenya, Tanzania and Nigeria, tilapia are now commercially raised in cages in the Ivory Coast (Balarin and Haller, 1982). Pen culture on the other hand has had limited development in Africa. Tested in Ivory Coast, Togo and Upper Volta the only major development has been in Benin (Balarin, 1984e) as a means of an alternative to the acadja. Although not yet complete, trials suggest yields of 25 - 220t/ha/yr.

4.3.6 Tanks and Raceway Culture

Tanks are generally circular or rectangular, constructed of concrete or metal and have long found use in trout production in Zimbabwe and more recently in Kenya and have been used for turtle farming in Reunion. Only in the last decade has this technique been applied to a food fish such as tilapia with pioneering work initiated in Kenya resulting in the development of the 'Baobab Tilapia Production System'(Balarin and Haller, 1982). This technique is now being considered for development in the Congo, Nigeria, Zambia and Zimbabwe.

Through intensive feeding of a nutritionally balanced, pelleted feed, yields upwards of an equivalent 2000/ha/yr are possible.

This system has the potential to produce the greatest amount of animal protein per unit area than any other known form of livestock industry. Further, the nitrogenous and solid wastes of the fish provide a natural fertiliser enhancing production, if used to irrigate crops. Solids can also be settled and used as a manure, or in biogass production. During the process, fish are size graded selecting for only 50% of the faster growers for ongrowing. Fish rejected and normal trade mortalities can be used to feed an integrated crocodile farm which also uses fish farm effluent waters. The high requisite for constant water flow, nearly 10m3 p.h. for every 1t p.a. fish production (or 80000m3/t/yr) implies that this system is only suited for integration with high volume, constant pumping, irrigation schemes. However the system can be modified for water recycling and would require considerably less.

5. SPECIES CULTIVATED

About 130 - 140 different species have been tested or are cultured in Africa.

5.1 Tilapia

By far the most popular and widely used species are the tilapia, endemic to Africa. Over 31 species of this group have been tested and the most common in use are *O. niloticus* (31 countries), *T. rendalli* (27 countries), *O. macrochir* (25 countries) and *T. zilli* (23 countries). *O. mossambicus, S. galilaeus* and to a lesser extent *O. spilurus* are also popular. The greatest emphasis on tilapia farming has been in Tanzania, Kenya, Zaire and Cameroon but 36 countries mention some form of tilapia culture. As already mentioned (Section 4), if uncontrolled, tilapia can overpopulate and stunt in ponds. This is perhaps the only disadvantage of the group, because its hardiness, good growth, easy reproduction, efficient conversion of plankton artificial feeds and its tolerance of a wide range of environmental conditions, make it a prime candidate for aquaculture in Africa. The possibility of its culture in brackish or saline waters further extend the scope for production in areas less favourable for other species. Often overlooked however is that tilapia are a lowland fish restricted to altitudes below 2000m. Both reproduction and growth are affected by temperatures below 22'C and for every 10'C rise in temperature growth increases by a factor of 2.4 times. The following equation therefore expresses maximum potential pond production with respect to altitude.

$$P = 6.29a - 2.92$$

where: P = Yield t/ha/yr

a = altitude in 1000m

Tilapia production therefore declines by a factor of 2.2 for every 1000m increase in altitude and it is for this reason that carp were introduced for regions between 1000 - 2000m and trout for cooler areas above 2000m.

5.2 Introduced Species

Trout (*Salmo gairdneri*) were perhaps the first fish species to be introduced and farmed in Africa, mainly Zimbabwe and Kenya, representing 73 and 30% of fish farm production in 1982. Trout initially introduced as eggs for angling purposes was transplanted into over 20 countries. The intensive nature of farming requires high technology and artificial feeds such that it is unlikely to develop to any great extent at village level. The same applies to Black Bass (*Micropterus salmoides*) and *Macrobrachium*; although the former has found use as a predator in rural tilapia ponds, its application is limited due to the complexity of hatchery techniques.

Other minor introductions to Africa include *Esox* (5 countries), *Ictalurus* (3 countries), *Salvelinus* (4 countries), *Tinca tinca* (5 countries) but development is poor. Others include such fish as *Lepomis* as a forage fish for Black Bass and *Gambusia* for mosquito control.

Perhaps by far the most important introduction has been the carp, *Cyprinus carpio* in 22 countries for cool climate aquaculture, *Ctenopharyngedon idella* in 15 countries for farming and aquatic weed control and *Hypophthalmichtys molitrix* in 9 countries. Although hatchery technology is a problem these species offer potential scope for future small scale fish farming in cool, high altitude areas. State operated hatcheries are essential and are currently being developed in Egypt, Ethiopia, Ivory Coast and Kenya.

5.3 Indigenous Species

The most frequently used species other than tilapia are *Barbus* (8), *Chrysichthys* (7), *Hemichromis* (9), *Heterotis* (10), *Labeo* (10), *Lates* (10), *Mugil* (8), *Penaeus* (11), *Serranochromis* (7) and the most popular are *Clarias* (21) and *Crassostrea* (12). Although total yields of these and other species are not high, interest exists to increase production and intensive research on *Clarias* in Central African Republic. The problem with most of these species is poor technical advancement such that most are either pilot or research projects. Perhaps *Penaeid* culture, because of its high market value, represents the next likely species to advance in production.

6. SCOPE FOR AQUACULTURE IN AFRICA

Between 3 - 4 million tonnes were landed in 1981 to feed a population of 484.5 million representing an average per capita consumption of 6.1 - 7.8 kg/ind/yr. An optimum requirement however to meet the daily protein requirement is considered to be 10kg/ind/yr. Over 50% of countries listed consume less than this amount. Notably Algeria, Ethiopia, Lesotho, Libya, Niger, Reunion, Rwanda, Sudan, Swaziland and Upper Volta consume less than 20% of optimum. In Congo, Ghana, Senegal and Sierra Leone, fish provide more than 15% of total protein. Ideally 5% of protein in any diet should be fish, this coupled with a low food production index makes such countries as Algeria, Botswana, Ethiopia, Kenya, Lesotho, Mozambique, Somalia and Zimbabwe potentially likely to benefit the most from an increased fish production including aquaculture.

Extrapolating from expected population growth by the year 2000 an estimate for fish requirement has been derived assuming that either present levels or an optimum 10kg/ind/yr are to be maintained. Africa would need between 5.4 - 10.4 million tonnes of fish and it can be considered that this may represent virtually double the potential maximum yield of all fishery resources. The deficit in fish protein budget would have to come from fish farming. An attempt to estimate the actual requirement of aquaculture is incomplete for lack of data.

Generalising, Balarin (1984h) estimates national fish production in Africa must be stepped up to yield 4.1 (+1.6) t/ha/yr and development rate of ponds in the order of 1820 ha/yr per nation at a capital cost of US$955 t/yr. Although these estimates are based on a sample survey of only 8 representative states, the demand nevertheless suggests that efforts must be stepped up if the future scope for aquaculture is to benefit mankind in Africa.

7. DEVELOPMENT RATIONALE

In conclusion therefore it is possible to examine the development potential of aquaculture. FAO estimates consider that tilapia culture alone in Africa has a potential to yield over 8 million tonnes production. Bell and Canterberry (1970), give country ratings considered to have the greatest scope for development and indicate 30 million hectares of coastline suitable for fish farming. Anon (1981) in an unpublished FAO model survey analysed the potential for development and obtained a mean rating for Africa of 0.98, below the world average of 2.44. In particular Benin, Gabon, Ghana, Liberia, Rwanda, Senegal, Sudan, Tanzania and Upper Volta were implicated as below average for development.

To meet food requirements, Africa could benefit from aquaculture production. However development strategy requires that at present production levels, vast tracks of land need to be converted to fish farms. This represents a physical and economically difficult task. Intensification is necessary but the requirement for technological inputs precludes any short term development. This calls for a consolidation of resources, a limitation of activities to a few species, preferably tilapia and carp and establishment of regional pools of manpower in the form of a network of aquaculture development centres.

TABLE 1
COMPOSITE OF 1965-85 AQUACULTURE STATISTICS: AFRICA

COUNTRY	*PONDS* *nos.*	*AREA* *(ha)*	*PRODUCTION* *(t/yr)*
Algeria			
Angola			
Benin	113-155	6-2000	5-2500
Botswana			
Burundi	352	65	
Cameroon	6000-12,000	10-200	10-273
Capverde			
Comoros			
Central Africa Republic	900-25000	33-43	43-105
Chad			
Congo	2120-12200	69-242	15-44
Djibouti			
Egypt	11300	2500-48850	2600-25000
Equatorial Guinea			
Ethiopia	10	1	1
Gabon	1500	-	5-27
Gambia, The			
Ghana	30	204	30-120
Guinea			
Guinea Bissau			
Ivory Coast	340	-	10-300
Kenya	12200-32140	610-3000	122-585
Lesotho			14-27
Liberia	95-300	7-73	10-350
Libya			
Madagascar	85000	1280-2000	300-17400
Malawi	370-1000	72-200	46-104

TABLE 1 *(continued)*
COMPOSITE OF 1965-85 AQUACULTURE STATISTICS: AFRICA

COUNTRY	*PONDS* *nos.*	*AREA* *(ha)*	*PRODUCTION* *(t/yr)*
Mali			
Mauritius	20	3-270	60-120
Mauritania			
Morocco			
Mozambique	250	10	
Namibia			
Niger			
Nigeria	300	61-2000	127-75000
Reunion			
Rwanda	448-2662	78-84	10-180
Sao Tome/Principe			
Seychelles			
Senegal			191
Sierra Leone	162	2	3-4
Somalia			
Sudan	37	30-60	30-50
Swaziland	250	20	
Tanzania + Zanzibar	8000-10000	1000	500-1800
Togo	514	8-60	
Tunisia	7		30-168
Uganda	11000	410	31-2300
Upper Volta	32-50	11	200-400
Western Sahara			
Zaire	122070	4000-4200	700-5000
Zambia	1230-1708	100-460	29-6000
Zimbabwe	5000	12500	800
TOTAL	269650-97215	23090-63742	5922-137857

TABLE 2

SUMMARY OF THE CHARACTERISTICS, INPUTS AND EXPECTED PRODUCTION OF TRADITIONAL AQUACULTURE SYSTEM TYPES IN AFRICA

System Type	*Dimension*	*Essential Inputs*	*Accessory Equipment*	*Expected Harvest Time*	*Seed Stock (n/ha)*	*Mean Havest Size (g)*	*Productivity Range (t/ha/Yr)*	*Characteristic Features*
Barachois/Lagoons	0.5 0/5-50 ha	Stone wall	Seine net	1/Yr	1000 (+wild)	100-250	0.1	- Shallow lagoon - High capital cost - Low depreciation
Fish Holes: a. Whedos	20-1500m trench	NIL	Net/traps	4 months	Wild	50-1000	1.0-2.1	- Flat flood plain - Minimal input
b. Ahlos	30m trench	Branches	Net	1/year	Wild	50-1000	1.0	
Howash	1-20 ha shallow pond	Earth dyke	Manures(opt) pump boat nets	1-10/years	1000-5000 (+ wild)	20-250	0.5-4.5	- Flood plain either coastal, lake-shore or delta
Acadja(Brush Park)								- Shallow lake/ lagoon
a) Amedjerotin	250-1250m^2 circle	Palm fronds	Canoe/nets	2/year	Wild	50-200	5.0-6.0	- High depreciation
b) Adokpo	250-4000m^2 groups	Branches	Canoe/nets	4-8 months (2/yr)	Wild	50-200	8.0-10.0	- High capital cost
c) Ava	0.2-7.0 ha rectangular	Branches	Canoe/nets	1-2/yr	Wild	50-200	4.0-21.0	
d) Hanou	20-150m^2 composite	Branches	Canoe/nets	2 months (6/yr)	Wild	50-200	up to 17.0	
e) Akadjavi	Vars. circle	Branches	Canoe/nets	Var	Wild	50-200	2.0-25.0	
f) Godokpono	20-150m^2 circle	Branches	Canoe/nets	4-5/year	Wild	50-200	6.0-25.0	
g) Aula	Var.	Branches Vegetation	Canoe/nets	10/year	Wild	50-200	28.0	
h) Hanoumecodjia	20-150m^2 composite	Branches	Canoe/nets	2-3/year	Wild	50-200	3.6-38.0	

TABLE 3

SUMMARY OF THE CHARACTERISTICS, INPUTS, AND EXPECTED PRODUCTION OF CONVENTIONAL AQUACULTURE IN AFRICA

System Type	*Essential Inputs*	*Accessory Equipment*	*Expected Harvest Time (days)*	*Seed Stock Size (g)*	*Most Common Harvest size (g)*	*Optimum Stocking Range (n/hax1000)*	*Productivity Range (t/ha/yr)*	*Characteristic Features*
1. Lakes and rivers	Fishing effort	Boats nets	Seasonal	N.A.	1-1000	5-50	0.2-0.5	– Low intensity
2. Rice Paddy stocking	Seed stock	Nets	90-120	5-10	50-70	10-20	0.3-1.5	– Simple technology – Minimal management
3. Dam stocking	Seed stock, Manure	Nets	Seasonal	5-25	50-200	10-50	0.3-1.5	▮
4. Ponds:								I – Feeding
a) Subsistence	Seed stock, Domestic wastes	Nets or Hook & Line	Intermittent	5-10	25-100	10-30	0.2-2.0	N C – stock density
b) Semi-intensive	Seed stock Fertilisers Manure/Waste Feeds	Nets (± Drainage)	Variable 180-365	5-25	50-250	10-30	1.0-5.0	R E – energy inputs
c) Intensive	All-male seed, animal-cum-tilapia manure (±Pelleted feeds) (±aeration)	Nets, drainage, harvesters, catch-box graders, water test kit	100-180 Often only partially harvested	25-50	150-250	20-50	5.0-12.0	A – flow or aeration S – capital investment E
d) Superintensive (often experimental)	All-male seed, manures & fertilisers, Pelleted Feeds Aeration or flow	Nets, drainage, harvesters graders, auto-feeders, water test kit	100-180	25-100	200-300	30-100	10.0-25.0	↓ – running costs – crop value
5. Cages (in ponds or Lakes)	Pelleted feeds, seed stock	Graders, auto-feeders water test kit (+/– boats)	100-180	10-25	150-250	50-2500	10.0-700.0	
6. Tanks and raceways	Seed stock, pelleted feeds, flowing water, aeration	Graders, Auto feeders, pumps, water test kit	100-180 As required	25-50	200-300	100-300	20.0-2000.0	High intensity – Complex technology – Demanding management

FISH INTRODUCTIONS

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1. Introduction

Though as early as 2500 BC Egyptians were known to keep tilapia in confined areas, organised aquaculture efforts on the Continent started only in recent times, particularly after the second world war (Meschkat 1967). However, fisheries from natural waters like lakes have been exploited from very early days (van der Lingen, 1967). Fish culture did not progress much because people were accustomed to cropping, gathering, herding and hunting. Though the lead was taken in aquaculture by the Congo, even before the second world war, it was only after the war that fish culture started in many African countries. It was estimated that there were about 27,236 ha of fresh and brackish water ponds in Africa out of the world total of 3,446,048 ha (Lennon et al, 1970). According to a recent FAO estimate the annual aquaculture production in Africa is around 10,000 tonnes. This is less than one per cent of the total world output.

Table I shows the approximate period that aquaculture was initiated in various countries and Table II depicts fish consumption in African Commonwealth countries.

2. Aquaculture and species cultivated

Aquaculture in most African countries has evolved around tilapias. Tilapia species were first tried in ponds in Kenya (Huet 1970, Barbach et al, 1972) and later successfully cultivated in Kalanga (Zaire). In addition to cultivating the locally available tilapia and other species, several species were introduced from outside the continent as well as transplantation from endemic to non-endemic regions. George (1975) describes 56 species of finfish and shell fish introductions to Africa. Presently it is reported that there are over 140 such transplantations, of which 34 are finfish and five shell fish. Seventeen species are considered non-endemic fishes of which 10 are tilapias.

The main reasons for these deliberate introductions as given by Jackson (1960) and George (1975) are:

(1) to enrich local fish fauna with fish that are more valuable, more prolific or desirable as sport or food fish, than endemic species;

(2) to control malaria, schistosomiasis or weeds in reservoirs and irrigation canals;

(3) to fill what have appeared to be unoccupied ecological niches;

(4) to produce hybrids and thus overcome cultural problems of some species.

Table 3 gives details of species introductions and the purposes intended.

3. Brackish water fish culture

In Africa, brackish water aquaculture is still in its very early stages. Most of the coastal African countries are endowed with estuaries, lagoons and an abundance of brackish water areas which have high potentials for aquaculture development. Some of the species offering potential for brackish water aquaculture are: *Sarotherodon melanotheron, Tilapia guineensis, T.zillii, Chrysichthys* spp, mullets (*M Cephalus, M Falcipinnis, M grandisquamus*), shrimps, oysters etc. On the West African coast, *Crassostrea tulipa* offers excellent prospects for culture.

In Africa the extensive system of aquaculture is practised in various ways; these include the draining of ponds, use of dug-out-ponds, Akadjas, blocking of natural flood plain depressions, fish culture in rich fields, pen culture, cage culture, and oyster culture including rock and raft culture.

Table I

Period of aquaculture initiation in different countries

Country	*Date*
Benin	1955
Egypt	1934
The Gambia	1979
Ivory Coast	1955
Kenya	1921
Malawi	1954
Nigeria	1951
Sierra Leone	1978
Sudan	1950
Tanzania	1940
Togo	1954
Uganda	1957
Upper Volta	1952
Central African Republic	1952
Zaire	1943

Table II

Fish consumption and production in African Commonwealth countries

	Fish Consumption			**Fish Consumption**	
Country	*Per Capita (kg/yr)*	*% Share of fish in total protein supply*	*% Share of fish in animal protein supply*	*Tonnage ('000T)*	
				Marine	*Fresh water*
Botswana	2	0.9	8.7	0	1.45
Cameroon	10.4	6.3	38.0	19.4	50.00
Gambia, The	13.6	8.1	36.5	11.0	1.00
Ghana	27.5	21.4	68.1	200.4	40.0
Kenya	2.7	1.3	5.6	4.5	55.9
Lesotho	–	–	–	–	–
Malawi	12.7	5.4	55.2	–	51.4
Nigeria	10.5	5.9	39.0	313.1	183.2
Sierra Leone	26.6	16.3	69.5	34.2	15.0
Swaziland	–	–	–	–	–
Tanzania	15.5	9.1	31.7	36.0	190.0
Zambia	12.3	6.1	–	–	–
Zimbabwe	–	–	–	–	–

Table III

Details of exotic species of fish and shell fish introduction

Reasons for Introduction		*No of cases*
Sport fishing		10
Stocking natural water		5
Culture:		
Pond culture		5
Rice fields		4
Rural fish culture		1
Biological control of unwanted species:		
Weed control		4
Malaria control		1
Snail control		1
Tilapia control		3
Forage (Black and feeding)		2
Filling vacant ecological niches		1
Hybridisation (Private enterprises)		8
Miscellaneous		2
Experimental		9
	Total	56

TECHNICAL AND SOCIOECONOMIC FACTORS INHIBITING DEVELOPMENT

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1. INTRODUCTION

Aquaculture development in Africa is believed to have started in Egypt 2500 years BC as depicted by bas reliefs of tilapia reared in ponds. This is even before carp culture was initiated in China, but despite this early start, fish farm production in Africa currently yields less than 0.1% of the world total of farmed fish. The reintroduction of aquaculture in Africa essentially took place after World War II. By 1960 over 320,000 ponds had been built in 30 countries. Over 140 species of fish were cultured but most countries chose the tilapia, in view of the ease of production. The high fecundity of this species in ponds can create overcrowding, resulting in a small end product. This undoubtedly discouraged farmers, for in the 1960s, interest declined. With the emergence in the 1970s of new fish farming concepts and a realisation that African small scale subsistence farmers could benefit, saw renewed activity such that by 1983 over US$ 100 million was allocated in aid grants (Anon, 1984). Large scale commercial enterprises however have hardly developed and only 10-15 projects are in operation, half produce under 100t/yr and there are about 20 pilot projects.

The 10-year development plan for Africa reported by FAO/ADCP in Ghana in 1975, (FAO, 1975) has far from reached its goal. At the time a contradiction in objectives and an absence of adequately trained personnel were concluded as the major constraints to development. Remedial action was recommended and a 10-year development plan for 9 countries planned to realise 514 500t/yr by 1985. Current production remains low, between 7-144 thousand tonnes, but statistics are confused and overestimated such that the lower value is more likely to approximate actual yields. Aquaculture therefore has a poor track record and Anon (1981) in an analysis of the situation suggests that between 1975-1980 aquaculture actually declined at a rate of 13%/year.

2. THE CONCEPT OF VILLAGE AQUACULTURE IN AFRICA

Characteristic of rural developments in Africa, village level aquaculture is generally small scale, operated either by individual subsistence farmers, artisanal or community groups employing relatively unsophisticated techniques for the purpose of additional food production often integrated with other farming systems. Practised as a sole or part-time occupation, often dependent upon public sector involvement either for funding or support services, production units are small and yields low.

Generally fish exist in harmony with their natural environment, natural selection having determined the genetic make-up most likely to be successful. Fish are therefore tolerant of a certain range of environmental conditions and can co-exist with a limited pathogen burden. An aquaculture system must strive to recreate optimum conditions, should stress occur due to any one unfavourable parameter a loss in performance or mortality results. This interrelationship is expressed in Fig. 1. The potential capacity for growth of a species is therefore determined by its genetic make-up; however the realisation of this potential is a feature of environment and stress within an aquaculture system (Fig. 2). Whereas the biological implications of this are beyond the present text, it is apparent therefore that village level aquaculture cannot be expected to develop just anywhere. To be a success, species selection is important to choose a fish capable of performing well under the prevailing conditions and management must ensure that the full potential is realised by optimising the growing climate (ie fertiliser, feeds, oxygenation, etc).

The tradition of fish culture in Africa is limited, with examples to be found mainly in Egypt, Benin, Togo, Mauritius and Cameroon. The implications are that before aquaculture can become common practice in rural sectors there is an absolute need for technological transfer.

Table I presents an analysis of the factors affecting developments after Anon (1981).

Discussed below are some of the factors inhibiting development, not necessarily presented in any order of importance.

3. TECHNICAL ASPECTS

Fish farming is a foreign concept to the rural farmer. Technical input is therefore necessary, but when aquaculture was first introduced to Africa, little was known of the biology of indigenous species. Introductions of exotics took place but the need for specialised hatcheries often placed these fish beyond village level practices. Pioneering efforts were necessary which meant the State had to bear the cost of research and later oversee the extension to the farmer. Poor understanding of the biology of the fish selected undoubtedly hampered early developments and still persists today. The group most favoured, the tilapia, also exhibit a unique trait of innate prolific breeding and soon there are more mouths to feed than food available. Fig. 3 illustrates that if only 5% of stocks are female, after 9 months if food is unlimited, 5t/ha/yr production can be achieved but the harvest would be of 250,000 fish, of which only 5% may be of a large and acceptable table size. Hand sexing for small males or use of predator stocking to control emergent fry are potentially unsophisticated techniques which could be employed by the farmer. More successful methods of hybrid crosses or hormone treatment to produce all males require technical input and a certain hatchery infrastructure which must be provided by the State as the level of technology and capital requirement is beyond the scope of the rural farmer.

Ironically, despite this problem of pond overpopulation, generally a large number of farmers are unable to obtain seed. Due to limited funds a farmer may only afford one pond. At harvest there is no means to hold potential seed fish (ie a second pond) and the farmer is dependent on other sources, generally his neighbour. Selection at harvest is for larger fish thus only smaller fish, assumed to be fry, are restocked or passed on. This presents a negative selection for size and in time farmers will be trading in genetically inferior stock. State hatcheries are essential to provide seed and to boost the genetic pool.

Therefore the state must bear the cost of research to develop techniques suitable for use under local conditions. Too often however research has been of an impractical nature often duplicating previous results. Hitherto unexplored is the use of tilapia in salt water, an environment in which the species can survive and grow but do not reproduce and therefore presents scope for mariculture by coastal villages or fishermen.

At subsistence levels generally extension agents are needed at a rate of 30 ponds per agent. Absence of adequate training institutions has meant that trainees have not kept pace with demand. Further, to be effective, extension agents need to be mobile (ie bicycle or motorcycle) an important feature in view of the distance between farmers. Extension agents need to work out of a centre which through its successful production of fish serves as demonstration and source of seed supply to farmers. Often however for reasons of insufficient funds, poor management or lack of incentive, such centres do not function and are a poor example for extension.

4. SOCIAL ASPECTS

Present demographic patterns emphasise a need to increase protein production and trends in world fishery landings suggest a limited scope for further increase in fish production. An alternative, such as fish farming, is therefore to be considered but a large portion of Africa has non fish eating traditions. Those areas most likely to benefit from increased fish production are generally those most distant from the fishery where it is often unlikely that people are accustomed to eating fish. Conversely introduction of fish farming in communities where the fishery is abundant is not likely to have the same incentive, for the long term benefits may not be immediately obvious and consequently Governments accord fish farming a low priority.

Conflict between use of manures as fertilisers for traditional crops and the use of crop by-products as well as domestic wastes as livestock feeds meant that aquaculture was in competition with long established practices. Compounded by the emergence in the 1960s of a new political reform, a bad track record and poor demonstration history meant aquaculture was abandoned for more traditional practices.

Government agencies, such as the Fisheries Department, were assigned the task of responsibility for village level fish culture development. However the low priority awarded to aquaculture meant little attention was paid to development, extension agents in the field lacked incentive, were poorly supervised, underpaid and generally of low morale such that they became disinterested in development. Staff rotation policy meant semi-trained persons were assigned extension work. Further, Fisheries Departments had a reputation for ensuring that fisheries legislation were implemented. Consequently extension agents were assigned law enforcement tasks. Suspicion amongst villagers meant that extension agents were distrusted, hampering any possibility of fish farm work.

5. ECONOMIC ASPECTS

The economics of an aquaculture operation are adequately summarised by Shang (1981):

$$Y = QP - C$$

Where Y = net income per unit area

Q = production

C = cost of production

P = price received.

Perhaps the most critical factor is that the low priority accorded to fish farming means that Government capital and recurrent budgets are low, often less than 1% of total Fisheries budget. Without funds all other aspects of extension are not possible. In an appraisal of the situation, Balarin (1984) considers African nations require to develop 1800 ha/yr of fish ponds to sustain fish protein requirement. At an estimated cost to the state of US$ 955/t output (1975 prices) each nation would have to spend annually USS 20 million on aquaculture. FAO estimates suggest US$60 million. Aquaculture development therefore is dependent upon external aid and up to 1985 over US$ 80 million is planned for projects in Africa with about US$20 million counterpart contribution. Major inputs are by the USAID/PVC in the form of extension services, French bilateral aid, FAO/UNDP support projects, IFS research grants and a mixture of capital item by EEC, World Bank, GTZ and ODA. In theory this aid should realise an additional 100,000t/yr production.

Traditionally, fishery resources have provided fish at low cost, often making fish protein the most inexpensive food item available to the rural poor. This low price therefore does not justify investment such that little commercial development has taken place. The cost of feeds and fertiliser supplements to enhance production can represent 50-70% of production cost and are therefore likely to find minimal use in village ponds where there is no surplus of such items. An integrated approach either combined with irrigation to make use of waters already pumped or to use irrigated crop wastes or weeds or in combination either in rice fields or with livestock rearing makes economic sense for a more efficient use of resources. Here lies the possible future trend in rural aquaculture.

6. CONCLUSION

In summary it is possible to say that the low priority given to aquaculture development has meant insufficient funds to develop techniques, establish the necessary infrastructure and adequately train sufficient personnel to provide an extension service. Absence of any tradition of fish farming has meant village projects are totally dependent upon Government inputs but the support given extension is lacking in incentives to increase production. This and the current low price of fish as well as a poor history of success has led to disillusionment and an abandonment of what once was a potentially thriving industry. To be a success massive foreign assistance is now necessary but emphasis must be toward intensification.

Fig. I The Interrelationships and Interactions between Fish, Environment and Pathology in an Aquaculture System which lead to Stress and Mortality.

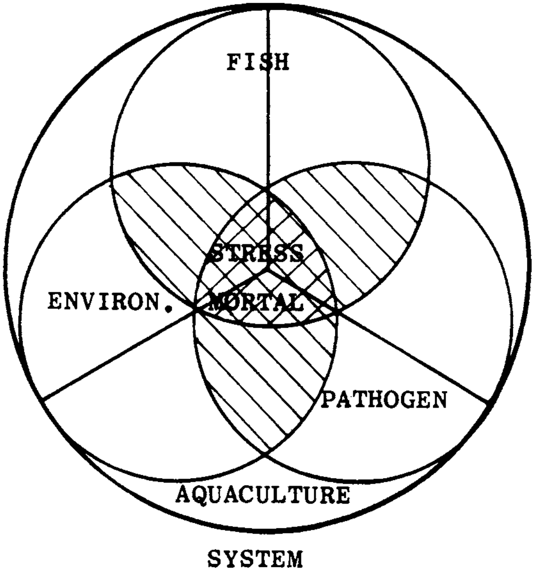

Fig. 2 The Relationship between the Potential and Realised Performance Capacities and the influence of the ultimate (genetic) and proximate (environment and stress) limiting factors on the geometric configuration of the capacities.

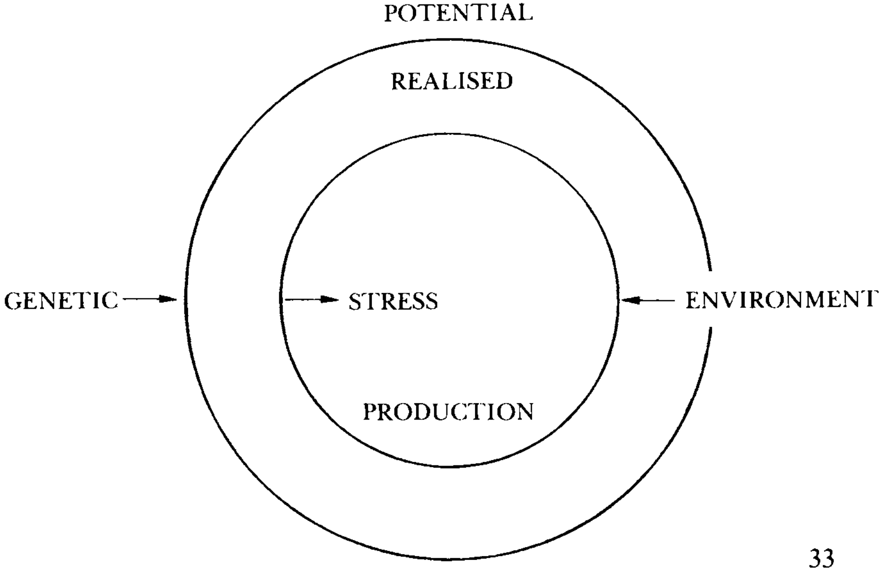

Fig. 3 Hypothetical Reproduction Potential of Tilapia in Ponds Stocked with only 5% Females

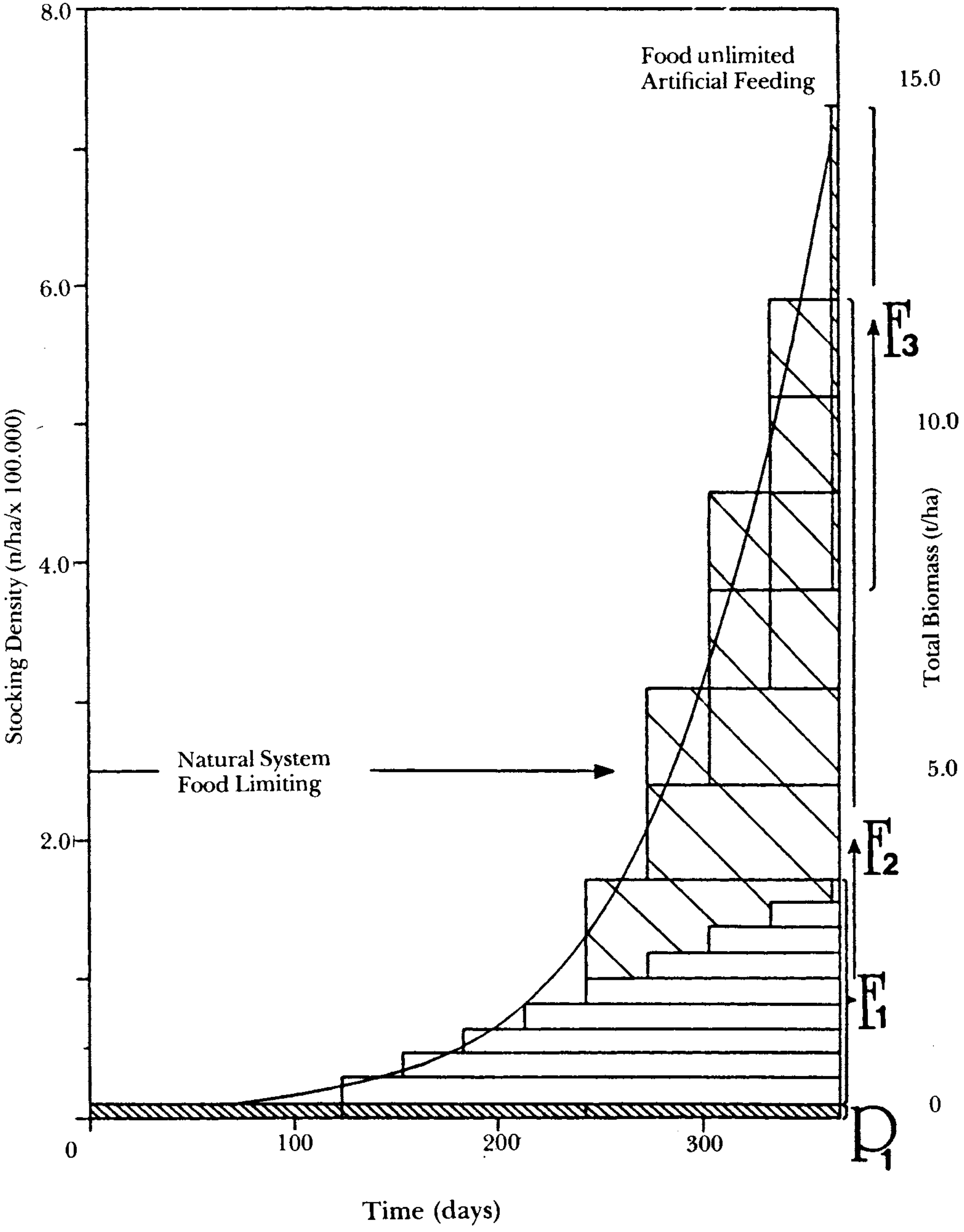

Table 1: Major Factors Affecting the Development of Aquaculture in Africa

FACTOR	SUB-FACTOR	COMMENTS	RATING	MEAN		SIGNIFICANT
			AFRICA	WORLD	VAR	DIFFERENCE
ENVIRONMENT	PHYSICAL	Suitability of land and water (including quality and quantity) in relation to requirements of aquaculture species	1.12	2.91	0.94	XX
	INSTITUTIONAL	Government policy, planning, programmes (such as training, extension services and financial assistance) and controls, legal requirements, political/economical stability	−1.08	1.88	1.77	XXX
	SOCIAL	Infrastructure, stage of political development, traditions, life style, education of level	−0.15	2.80	1.72	XXX
SPACE	LAND	Availability of space for aquaculture at acceptable cost	1.29	2.52	0.82	XXX
	WATER	Availability of space in lakes, bays, coastal zone for aquaculture at acceptable cost	1.00	2.46	0.76	XXX
TECHNOLOGY	CULTURE METHODOLOGY	State-of-the-art for growing selected species and local availability of methodology	0.35	2.59	1.33	XXX
	PRODUCT TECHNOLOGY	State-of-the-art of handling, preservation, processing, packaging, storage, distribution and local availability of methodology	1.23	3.23	1.33	XXX
PRODUCTION	PLANNING/MANAGEMENT	Business decision re-site selection, plant design, culture-system, operations, capital formation and business management	0.04	2.23	1.32	XXX
	INPUTS	Availability of seed, feedwater, utilities and materials at acceptable costs	1.69	1.81	0.34	NSD
	OPERATIONS	Management, labour, and farm operations needed to grow selected species to marketable size	−0.15	1.76	1.30	XXX
	COSTS	Fixed and operational costs in relation to revenues	2.00	1.74	0.32	NSD
MARKETING	PLANNING/MANAGEMENT	Decisions re-product form, processing methods, marketing strategy and business management	1.19	2.56	1.28	X
	DEMAND	Domestic and export demand and prices	2.54	2.88	0.57	NSD
	OPERATIONS	Processing, preserving and packaging the products, distributions and quality control	1.27	2.44	1.13	X
	REVENUE	Market development, sale price in relation to production and marketing costs	2.38	2.74	0.38	NSD
	OVERALL MEAN RATING		0.98	2.44	0.98	XXX

KEY: −5 = Unfavourable; 0 = Neutral; +5 = Favourable; *SOURCE:* Anon (1981)

IMPROVING AQUACULTURE SYSTEMS

DEVELOPING PRODUCTIVE SYSTEMS UNDER VILLAGE CONDITIONS

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1. CHARACTERISTICS OF VILLAGE AQUACULTURE

Currently, aquaculture in Africa is generally practised at three levels:

(i) small-scale rural fish farming or village fish farming (also known as small-holder fish farming, or fish farming in home-ponds, or family fish farming);

(ii) medium-size or artisanal fish farming involving fish-farmers/ entrepreneurs;

(iii) large-scale commercial or industrial aquaculture.

Out of these three categories of aquaculture, only small-scale and artisanal fish farming is so far practised in rural Africa, due to the socio-economic conditions prevailing in the rural areas.

1.1 Village fish farming or small-scale rural fish farming

'Village fish farmers' or 'small-scale rural fish farmers' should be considered as the owners of one or more small fishponds of an average surface area of between 100 and 300 m2 per pond, with yields of 10 to 30 kg fish per 100 m2/year (or 1 to 3 tons/ha/year), consuming a relatively important part of their production whilst marketing a small surplus. The ponds are generally fertilised using compost and manure and the fish fed with different locally available ingredients.

In village fish farming, investment is typically self-financed and the fishponds are managed by the owner and his family.

1.2 Artisanal or medium-size fish farming

An 'artisanal fish farmer' or 'medium size commercial fish farmer/entrepreneur' is generally an already experienced small-scale fish farmer, the owner of one or several relatively bigger ponds (from 300m^2 to 2000 or 3000 m^2) producing over 3 t of fish per ha/year. This type of fish farmer could also be the owner of some floating cages (each about 20m^3) installed in a reservoir or a barrage-pond. The artisanal fish farmer generally practises polyculture and fish culture integrated with animal husbandry. An artisanal or medium-size fish farmer may have received financing and will apply intensive fish rearing techniques: fertilisation of the ponds, intensive feeding of the fish and fish culture combined with animal husbandry.

Based on experience in some African countries (Central African Republic, Ivory Coast and Zambia, for example), it is fully possible that, starting with small-scale rural fish farming, after 2-3 years of intensive extension work, some progressive fish farmers (about 15-20 percent of the 'small-scale' rural fish farmers) would be capable of improving their yields through more intensive fish farming techniques such as polyculture and integrated fish farming with animal husbandry (pigs, ducks and chicken, for example).

2. MEANS OF IMPROVING THE PRODUCTION OF FISH IN PONDS

According to Huet (1975), non-biological and biological methods can improve fish production in ponds.

2.1 Non-biological methods

2.1.1 Maintenance of ponds and their improvement

Apart from normal maintenance of dykes, banks and water inlet and outlet, other actions are to be taken to maintain and improve the ponds: weed control and maintenance and improvement of the pond bottom fertility.

(i) Action to prevent infestation by aquatic plants: is only necessary when weeds become excessive or when they are not useful as food for fish. It should, however, be borne in mind that aquatic vegetation in ponds is an important element in the biological cycle in ponds (macrophytes, phytoplankton, periphyton), but only when growing in a relatively small part of the pond area. Excessive aquatic vegetation competes indirectly with the fish using the nutrients for their own growth, accelerates silting, creates a pond bottom rich in cellulose, provides refuge for predators, hinders the use of seines and other nets during intermediate fishing for sampling and makes pond drainage and harvesting operations very difficult.

Maintenance of ponds is far more easy when unwanted plants are regularly removed than when the pond has to be completely restored when invaded by weeds and is silted up. Removal of excessive aquatic weeds may also reduce snails, some of which are intermediate hosts of bilharziasis or schistosomiasis. Weed removal also reduces the potential breeding areas of mosquitoes, vectors of malaria.

There are three methods used to control excessive aquatic vegetation: mechanical cutting, chemical methods and biological methods. In village fish farming, fish farmers usually remove excessive weeds by hand, but the principal biological method is the use of herbivorous fishes (*Tilapia rendalli, T.zilli* and the grass carp *Ctenopharyngodon idella*, is also recommended.

(ii) Maintenance and improvement of pond bottom fertility: is necessary to improve the physical, biological and chemical condition of the soil. The soil of the pond bottom, and particularly mud, are the 'production laboratory' of the pond, since the nutrients are absorbed by the mud. The nutrients contained in fertilisers act on the mud and the pond bottom, and indirectly on the water mass or the organism in suspension.

Ponds are generally drained for cropping and left without water over a certain period. The drying out of the pond must be effective, to benefit from drying and exposure to the sun and air. To allow drying out, the pond bottom should have a good network of drainage ditches, which have to be cleaned out after the water has been drained off. The drying out period must be short, to avoid a loss in production. It should only last long enough to obtain the mineralisation of the mud, which will be evident when the bottom surface cracks (Huet, 1975).

Light tillage of the dried out pond bottom and the working in of lime and manures restore pond productivity. It is also during the drying out period that excessive mud or silt should be removed from the pond. This mud is generally very fertile and can be used as fertiliser in vegetable gardens.

Repairs and maintenance work should also be carried out during this period (repairs to outlet, inlet and monk; filling of cracks; removal of weeds and other unwanted vegetation rooted in the bottom in the shallow part of the pond, etc.).

2.1.2 Liming and fertilisation of ponds

Liming has not yet become a current practice in small scale rural fish farming in Africa, even if liming of ponds is considered beneficial and has a favourable action on some biological factors of production and on the health of fish.

The most important reason for liming in village ponds is to avoid or to correct acid conditions in the pond (pH less than 6-6,5) and when the alkalinity is too low. Testing the water and soil quality is necessary when planning fish farming and is one of the many tasks of the fish farming extensionist: the pH could be between 4.0 and 6.0.

Fertilisation of the ponds increases fish production substantially and, apart from artificial feeding, fertilisation provides the best means of increasing fish production in ponds.

Either inorganic or organic fertilisers may be used. Recent increases in the price of mineral fertilisers has greatly limited their use in rural areas, taking also into account local transport problems, especially in remote areas. Inorganic fertilisers (mineral or chemical fertilisers) include single and double superphosphate, ammonium sulfate, urea, etc.). Organic fertilisers might include animal manures, compost and artificial manure; the latter is made by composting vegetable matter and adding urea or some other source of nitrogen. Artificial manure is not yet commonly used in fish ponds in Africa but could be of interest in countries where chemical fertilisers and animal manures are scarce.

The principal aim of fertilisation is to increase the quantity of natural food in the pond. In fact, fish production depends on the relative quantity of inorganic nutritive substances available in the pond, provided that there is enough heat and light.

Organic fertilisers such as animal manures (mainly from chickens, pigs and cattle) and compost are often found only in relatively small quantities and, therefore, their use in large commercial fish farms is limited, due to the bulk involved and the cost of labour. On the contrary, the use of such organic fertilisers has become more and more popular in village fish farming in some African countries, since they are easily and locally available and cost the farmer almost nothing.

Animal manures contain nearly all of the nutritive substances indispensable for a normal biological cycle in the pond, which is not the case when using mineral fertilisers. The application of manure to fish ponds stimulates plankton growth and can increase fish production several times over natural production.

In newly built ponds, where the pond bottom is relatively sterile due to the absence of mud, the application of manure is recommended to improve the pond bottom.

The rates of manuring ponds depend again on the natural fertility of the pond. Several authors recommend different rates of application, according to the prevailing physico-chemical conditions in the ponds in tropical areas.

Quoted from Huet (1970), Snow *et al* (1964) and the Centre Technique Forestier Tropical (1972), Miller (1976) has summarised the advantages and disadvantages in the use of organic fertilisers.

When manure is not readily available in the village, one can utilise compost for the fertilisation of ponds, as is practised in rural ponds in the Central African Republic, Kenya, Ivory Coast and in other countries where village level fish farming is practised.

The use of compost to maintain pond fertility will reduce the farmers' dependence on chemical fertilisers which are generally imported and paid for in foreign currency.

There are two methods to convert organic matter into compost for fertilisation of ponds:

(i) the anaerobic method: consists of organic matters (grasses, spoiled fruits, leaves, wastes from soaking cassava, etc., and some cattle or chicken manure) stacked underwater in a pile in the corner of the filled pond. For a 100 m2 pond about 50-60 kg of organic matter is required to start with. The heap of organic matter in the pond is placed in a small fenced enclosure of crib made of wooden poles and bamboo. Weekly doses of 8-10 kg organic matters are generally added to the pile. To collect, transport and pile the organic matter for composting a 100 m2 pond, a farmer may spend an average of 28 hours a year;

(ii) the aerobic method: consists of the decomposition (rotting) of organic matter in compost piles in the open air, and thus not underwater; the biological process requires adequate aeriation and the compost pile should be turned over regularly.

Natural productivity in ponds in Central Africa is about 150-200 kg per ha/year. In the monoculture of *Tilapia nilotica* (stocking density: 2 fingerlings/m2, the average production from ponds where anaerobic compost is used, is 1500 kg of fish/ha/year. In the same conditions, but using aerobic prepared compost, production can reach 3,000 kg of fish/ha/year, with an application rate of 20-30 tons compost per ha/year (CTFT, 1972). These results were obtained with the composting of not only grasses, but also manure and wood ashes (rich in minerals).

Another technique for manuring fish ponds is the combined rearing of fish with pigs, ducks or chickens, in enclosures built beside or over the fish ponds. These integrated farming systems are well adapted to the socio-economic conditions of small-scale farmers, who make up the bulk of the rural population in almost all African countries. Associated rearing of fish and livestock have yielded some of the highest levels of fish production in ponds in Africa (up to 10,000 kg of fish/ha/year), utilising only excrement and waste feed from the animals (Miller, 1976; Vincke, 1976).

Fish/livestock integrated farming systems, suitable for small-scale farmers, are presented in section 3.3.

2.1.3 *Artificial feeding of the fish*

As village fish farming is based on simple and unsophisticated techniques, the available feedstuffs are not processed, except for some ingredients which are milled using a hammer mill, if available in the village. Other ingredients are only crushed in a mortar (cotton seeds, for example). The different raw ingredients are mixed and scattered by hand over the pond surface. Only hand feeding is practised in village ponds and allows the farmer to see the fish every day and to check their behaviour. He can also, at the same time, check the water level in the pond, clean the screens, etc.

Even if there is a lack of information on the vitamin requirements of tilapia and on their mineral requirements (Jauncey and Ross, 1982), fish feeding technologists still recommend the incorporation of vitamins and dietary minerals in diets for tilapia raised in ponds. They also recommend the use of animal proteins in tilapia feeds. It seems that tilapia reared in ponds get all their vitamins and required minerals, and a fair amount of protein, when consuming the natural food available in the pond.

The results of experiments in ponds have demonstrated two facts: it is not always necessary to feed a pelleted feed to obtain the best yields in tilapia culture in ponds; animal proteins may not be required in rations for tilapia reared in ponds, if the animal proteins are replaced by adequate vegetable proteins.

It has been demonstrated (Swingle, 1968) that there was significant benefit, to feed conversion rate, for channel catfish (*Ictalurus punctatus*) and common carp (*Cyprinus carpio*) if the feedstuffs were pelleted. This is however not the case for *Tilapia nilotica*, as shown by Miller (1977), and for *T. aurea*, as demonstrated by Allison *et al* (1976). This finding is of practical significance to those who wish to culture *T. nilotica* or *T. aurea* in ponds and who are considering the acquisition of a pelletiser, on the supposition that pelleting feedstuffs is necessary for efficient utilisation of food in ponds (Allison *et al*, 1976).

The experiments on the comparative use of animal and vegetable protein conducted by Hastings (1973) in *T. nilotica* monoculture in ponds have demonstrated that vegetable proteins in pellets can be substitutes for animal proteins in rations of 30 percent protein. A greater production (7.167 kg/ha/year) was obtained in feeding the 30% vegetable protein diet, compared to the animal protein diet (4.718 kg/ha/year), according to Miller and Maletoungou (1976).

2.2 Biological methods

2.2.1 Careful choice of species

The choice of species should not only be based on technical criteria (easy reproduction of fish, rapid growth etc.), but bearing in mind also socio-cultural aspects (the habit of not consuming fishes without scales, for example) and economic aspects (choice of species to be cultured depending on the purchasing power of the consumers).

2.2.2 Control and adaptation of pond stocking

Stocking density depends on the total productivity of the pond. The total productivity of a pond is the sum of natural productivity and the added productivity due to fertilisation of the pond and artificial feeding (or supplemental feeding) of the fish. The stocking density depends on the productivity of the pond, aiming at obtaining maximum quantity and quality of fish under the best economic conditions (lowest financial inputs).

High stocking densities result in a better use of natural food than reduced stocking, and, generally speaking, leads to a higher yield or higher quantitative production. Quantitative production means a production which will give the total maximum weight possible, but the fish will not be graded and not be of the best quality. This is the case in village fish farming, where tilapias of less than 60 g are easily sold in local markets. Thus stocking large numbers of fingerlings will result in an increase in total production, but in a reduction in the average weight and the size of the individual fish produced.

As demonstrated by Micha (1973), when using *Tilapia nilotica* fingerlings at stocking densities of 10.000, 20.000, and 30.000 per ha (or 1,2 or 3 fingerlings per m^2) and fed brewery waste (draff), the total yield during a rearing period of about 7-8 months, passes from 1700 kg/ha/year with a stocking rate of 10,000 fingerlings per ha to 4.390 kg/ha/year with 30,000 fingerlings/ha. The average weight of the adult fish is 136g at the density of 10,000/ha; 101 g at 20,000/ha and only 82 g at 30,000/ha.

The stocking densities should thus be adapted to meet the requirements of the villagers. The demand is generally for a maximum production even if the fish produced is not of a large size. In tilapia pond culture the recommended stocking rate is about 20,000 fingerlings/ha or 2 fingerlings per m^2.

2.2.3 *Control of temperature and oxygen content in ponds*

The water temperature is one of the most important external factors which influence fish production, since temperature has an important influence on breathing, growth and reproduction of fish. This considerable influence of water temperature is due to the fact that fish are cold blooded, which means that their body temperature varies, with the temperature of their environment.

Each species is adapted to a more or less wide range of water temperatures, including minimum and maximum temperatures, outside which they cannot live. Maximum growth of the fish and the maximum production of the pond occurs also in a scale of intermediate temperatures.

Optimum growth of common carp (*Cyprinus carpio*) is between 18 and 28°C and the optimum water temperature for reproduction is 18-20°C. The commonly cultured Tilapia species have their optimum growth between 20 and 26°C and the optimum reproduction temperature is 21 to 23°C. Fish kills can occur in ponds when the water temperature is too high and reaches the upper lethal limit (generally 35°C for Tilapia).

The best way to control the water temperature is to increase the quantity of water admitted to cool down the water in the pond and, alternatively, to reduce the inflow if the temperature should be increased.

The dissolved oxygen content depends on the pond water temperature, the submerged aquatic vegetation and the presence of organic matter. The warmer the water, the lower the dissolved oxygen content. Pure water at 0°C contains 14.62 mg/litre and only 7.63 mg/litre at 30°C (Huet, 1975).

The dissolved oxygen content should be 9 mg/litre for salmonids (trout), around 6-7 mg/litre for cyprinids (common carp, Chinese carp, etc.) and around 2-3 mg/litre for tilapia. It should be noted that some tilapia species are able to survive oxygen levels as low as 1mg/litre. This is also true for *Clarias lazera.*

The decomposing organic matter will absorb dissolved oxygen in the water and, if decomposing organic matter is too abundant, the dissolved oxygen content could then fall below the minimum level acceptable to the fish. The fish will then come to the surface in an effort to breathe air and other fish will group together near the fresh water inlet. The danger is particularly great in warm and thundery weather.

Given the present nature of village aquaculture, only inexpensive measures can be taken to increase the dissolved oxygen content in pond water. These measures are:

(i) to build into the water supply canal, small cascades or waterfalls to aerate the water;

(ii) the water inlet should be above the water surface of the pond and water can splash over a perforated screen, which will allow good contact with the air and enrich the water with oxygen;

(iii) introduction of semi-submerged water plants, such as watercress (*Nasturtium officinale*), fool's watercress (*Apium nodiflorum*) in the water supply channel to replenish the oxygen in the water;

(iv) introduction of submerged plants into the pond, such as horn-wort (*Ceratophyllum* sp.), water milfoil (*Myriophyllum* sp.) and pondweed (*Potamogeton* sp);

(v) reducing the organic matter by working it into the pond bottom;

(vi) cutting the emergent weeds to promote the penetration of light;

(vii) letting into the pond of fresh, good quality water, particularly during hot and thundery weather, when 'gulping of air' is noted in the ponds.

2.2.4 Improvement in reproduction and selection

Tilapia species, generally used in Africa for stocking village ponds, reproduce naturally in growing ponds (uncontrolled natural reproduction) and without difficulty. In some cases, however, they reproduce too frequently, leading to overpopulation in the pond and dwarfing (or stunting) if the production cycle is too long.

Other species reproduce naturally in ponds but with some difficulties and the number of fry and fingerlings obtained in ponds is relatively low. This is the case for species such as common carp, *Clarias lazera* and *Heterotis niloticus*. The reproduction of these species can be improved or be induced using special techniques that, up until now, were only applied in fingerling production centres.

Common carp are reproduced in spawning ponds (controlled natural reproduction) using 'Kakabans'. The 'kakabans' covered with eggs are removed from the spawning ponds and put into special cages for incubation and hatching. This is to avoid predation during the first life cycle of the fry.

Induced spawning using pituitary extracts and hormones which provokes the spawning of *Clarias lazera* and common carp and the use of techniques of artificial incubation of the eggs has made it possible to obtain a high number of fry, not only during the normal natural spawning period, but even during other periods of the year. This has extended greatly the culture of these species, even if some difficulties have to be overcome.

Undesirable production can be controlled by introduction in the tilapia ponds of voracious or carnivorous species such as *Lates niloticus*, *Hemichromis fasciatus* and also *Clarias lazera*.

Since the males of tilapia have a superior growth rate to the females, monosex cultivation (or rearing of all males) is also a way of improving yields in ponds. In male mono sex culture, the adverse effect of prolific breeding and low growth rates are avoided. It is thus a means of eliminating unwanted spawning in production ponds and stunting.

There are several methods to obtain all male fingerlings for stocking production ponds: manual sorting of males, hybridisation and sex reversal, but of these methods, only sorting of sexes could be practised in rural fish farming.

Selection has shown important possibilities for increasing production. This is particularly true for common carp and has produced races of different colour, different squamation (scales, mirror, naked) and different shape indices.

The possibilities of increasing production through selection of indigenous fishes have not yet been sufficiently used in Africa, but it is known, for example, that there are different strains of *T. nilotica* having differences in growth.

2.2.5 *Mixing of species and age groups*

The aim of the mixing of species and age groups is to improve quantitative, qualitative and economic production. A well planned combination is beneficial to each of the groups raised together in ponds.

Several combinations are possible, but in village fish farming only some of these are suitable.

An association of different age groups of the same species (also called mixing of non-voracious species) such as *T. nilotica* (adults mixed with juveniles and small fingerlings) will increase the quantitative production of fish for consumption. Fish from different age groups of the same species have generally different feeding habits and when mixing them in the pond, better use is made of food and the total production is increased. It appears that these different age groups do not compete with each other.

This method, known as the mixed age group method or the mixed method, produces a high quantity of small size tilapia. This simple method was used in the fifties and has now almost been abandoned everywhere and replaced by the so called separate age method. This is in fact a monoculture, stocking the production ponds only with fingerlings of almost all the same size. This is now the method used in small-scale rural fish farming in most of the African countries where fish culture is practised.

It is well known that a single species (monoculture) cannot use completely all the nutritive resources of a pond since each species has its own feeding habits and shows food preferences. Thus by mixing different species, more food resources of the pond will be consumed and the total production will be increased.

At the beginning of fish farming in Africa, the herbivorous *T. rendalli* (previously known as *T. melanopleura*) was cultured in polyculture with the microphageous *T. macrochir*. In Madagascar, common carp and tilapia species are cultured together in ponds and in irrigated rice fields, without harm since they have complementary feeding habits.

In Central Africa, *T. nilotica* is raised together with *Clarias lazera* and in this polyculture yields up to 4,950 kg/ha/year (average of 5 trials) were obtained during a production period of 100 days. In monoculture of *T. nilotica* in almost the same conditions (stocking density 2 fingerlings/m^2 and production cycle of 120 days or 4 months) the average yield of 6 trials was 3.651kg/ha/year. The increase in production due to the polyculture was thus 1.299 kg/ha/year.

Polyculture will only be successful if the species reared together have complementary feeding habits and occupy different ecological niches in the pond.

2.2.6 *Successive production cycles throughout the same year*

To obtain maximum production, it is recommended that ponds are kept under water as long as possible and produce several fish crops during the same year, if climatic conditions (particularly water temperature) allow normal growth of the fish during the whole year, and if fingerlings are available, when required.

At the end of each production cycle of between 3 and 6 months, the ponds are drained for harvest and, after a short drying out period, are restocked for a new production cycle. During a short production period, and in order to obtain table sized fish, it is necessary to stock the ponds with relatively large fingerlings (10 - 20 g) and to fertilise the pond and feed the fish regularly.

In order to avoid too high a percentage of tilapia fry and small tilapias, it is recommended, when stocking the pond, to add 10 -15 small *Clarias lazera* fingerlings (average weight 10 - 12 g) per 100 m^2 of pond. They will eliminate a large part of the tilapia fry born in the pond during the production period.

2.2.7 Intermediate fishing

Intermediate fishing (using cast nets, lines, seine nets, etc) is necessary when the density of the population in the pond has become too high. It could also be that the farmer wants to sell some of the fish during the rearing period and before the final harvest. This thins out the fish of saleable size which will provide remaining fish of small size more room and food to reach adult size.

It is generally accepted that intermediate fishing of large fish in the pond will increase the total population, but there is also the risk that the remaining smaller fish (particularly tilapia) will also start spawning and this will accentuate the overpopulation in the pond. Intermediate fishing cannot be repeated several times. Periodical drying out of the ponds is necessary to control overpopulation or overstocking and to remove unwanted species which will have entered the pond through the water supply channel or inlet.

2.2.8 Actions against predators, parasites and diseases of fish

In some countries, the most important predators of fish in ponds are otters. They may be trapped but the best way of protecting fish ponds against otters is to put a fence around the pond.

In other countries, birds such as cormorants, herons, hamerkops, kingfishers and fish eagles are the worst predators. Of these the cormorants are the greatest fish eaters and should be controlled under all circumstances.

Frogs, snakes and some aquatic insects eat young fish but no special action is generally taken against them, except drying out the ponds or by poisoning the pond water.

Predatory fish sometimes get into the ponds coming down from the water supply channel. This can be avoided by using appropriate screens at the pond inlet.

Parasites occur under natural conditions in rivers, lakes, reservoirs and also in ponds. According to Roberts and Sommerville (1982), parasitic infections of tilapias have generally shown no evidence of clinical effects on the fish and in most wild populations of tilapias, it would seem that parasites are a normal occurrence of little consequence, at least in low density systems such as rural fish ponds.

It has been admitted that in properly managed ponds, regularly harvested and dried out, there should not be any serious or fatal disease of fish. Tilapias are extremely resistant and are not known to succumb to endemic diseases when reared in ponds at adequate densities.

3. PRODUCTIVE SYSTEMS SUITED TO VILLAGE AQUACULTURE

Going by the experience of forty years in rural African small-scale fish farming, the systems best suited to village fish farming are: the culture of tilapia in earthern ponds (monoculture), polyculture in ponds using tilapia as the main species, mono or polyculture of tilapia combined with animal husbandry and rice-cum-fish culture or rizipisciculture.

In recent years cage culture of *T. nilotica* has been practised by artisanal fish farmers, namely in the Ivory Coast, although this is still on a pilot scale.

3.1 Monoculture of tilapia in ponds

This production technique is, so far, the easiest, and also the most successful method, for starting village level freshwater aquaculture. The main tilapia species cultivated in monoculture on village level in Africa are *Tilapia nilotica* (the most cultivated species in Africa), *T. Anderson ii* (confined mainly to Zambia) and *T. shirana* (only in Malawi).

Stocking densities, in tilapia monoculture in ponds, are generally between 1 and 2 fingerlings per m^2 (or 10 000 to 20 000 fingerlings per ha). Average size of fingerlings varies between 5 and 10 g.

The ponds are fertilised using manures or compost. Artificial feeding of the fish, using locally available ingredients, is generally practised, but is irregular and limited to a small variety of foodstuffs, often of low nutrient value.

With this kind of pond fertilisation and feeding of the fish, the production cycle is about 5-6 months and the yields are between 1.500 and 4.000 kg of fish per ha/year (or 15 to 50 kg per year in a 100 m^2 pond). These annual yields are obtained in two production cycles per year.

At harvest, the percentage of food fish (average weight between 60 and 100 g) is generally between 60 and 80% of the total weight and the rest is composed of fry and fingerlings, a proportion of which will be used to restock the pond for the next production period.

This rearing system is well adapted to village level fish farming and is particularly suited to beginners. Once they have mastered the elementary techniques involved and have gained sufficient technical skills, they can start the implementation of more intensive production systems such as polyculture and integrated systems.

A production of 15 to 40 kg fish per year in a 100 m^2 pond is usually not considered very impressive but for a villager, who consumes only about 6 to 8 kg of meat or fish a year, this fish that he has produced himself is a big improvement in his diet and can produce an additional income for his family.

3.2 Polyculture in ponds

Natural food in ponds, increased by fertilisation, and supplemental feeds, is not completely consumed if only one species is cultured in the pond. Higher yields can be obtained with polyculture, compared to tilapia monoculture.

In most of the polycultures, tilapias have been the main species used; this has been largely due to the difficulty in obtaining fingerlings of other species, such as *Clarias lazera, Heterotis niloticus* and common carp on a regular basis.

Polycultures are now practised in several African countries using *T. nilotica* as the main species, combined with *C. lazera*, common carp and sometimes *Heterotis niloticus*. Other combinations are *I. Andersonii* with common carp (Zambia), *T. shirana* and common carp (Malawi) and common carp and silver carp (*Hypophthalmichthys molitrix*) or grass carp (*Ctenopharyngodon idella*) in Lesotho.

In Central Africa, in polyculture of *T. nilotica* (200 fingerlings/100 m^2) and *C. lazera* (between 50 and 150 fingerlings/100 m^2, fed 30% vegetable protein pellets, the total production reached 4 950 kg/ha/year (average of 5 trials) during a production period of about 100 days. In *T. nilotica* monoculture (200 fingerlings/100 m^2), fed the same pellets and during a rearing period of 200 days, the yield was 3.651 kg/ha/year (average of 6 trials).

The species to be used in polycultures should live in different ecological niches and should have complementary feeding habits.

Several combinations have been proposed by different authors, depending on the kind of natural food available in the ponds and the kind of supplemental feed distributed. The most common associations are:

- Tilapia species (plankton feeders) and common carp (omnivore)
- *T. nilotica* + *Hemichromis fasciatus* (predator)
- Tilapia species + *Heterotis niloticus*
- *T. nilotica* (phytoplankton feeder) + *T. rendalli* (herbivore).

To these combinations, one can add some *Haplochromis mellandi* or *Arsatoreochromis alluaudi* fingerlings (about 10 fingerlings/100 m^2) to control snail populations (vectors of bilbarzia).

3.3 Fish culture combined with animal husbandry

Simultaneous production of fish in ponds, combined with pig, duck or chicken rearing in pens, beside or over the ponds, is now considered as one of the most promising productive systems for rural Africa.

This production technique constitutes a continual organic fertilisation of the pond by the livestock and is very productive, not only in polyculture of *T. nilotica* or *T. Anderson ii* with common carp, but also in other combinations. This practice increases the efficiency and rentability of both livestock farming and fish culture through the profitable utilisation of animal and feed wastes. In this system the fish do not generally receive any artificial feed. This integrated farming system has produced some of the highest fish yields in ponds in Africa (Vincke, 1976).

3.3.1 Fish-cum-pig culture

Pigs are reared in pens or styes built on the margin of the ponds or constructed over the ponds on piles. The number of piglets recommended is 100 per ha (or 1 piglet per 100 m^2 of pond). It is estimated that an adult pig produces an average of 3 tons of manure/year. Piglets are weaned at two months (weight between 12 and 15 kg) and are ready for fattening. With proper feeding, the average weight of market pigs is 70 - 72 kg after 6 months and about 85 kg at seven months.

In ponds stocked with *T. nilotica* at a rate of 2 fingerlings/m^2, the production can reach 8,000 kg of fish per ha/year and 6,000 to 9,000 kg of pigs (on the hoof) per ha/year (Vincke 1976).

With *T. Andersonii* (monoculture), combined with pigs, 7,000 kg of fish per ha/year were obtained in Zambia. Monoculture of *Clarias lazera* with pigs yielded 7,510 fish per ha/year in Central Africa. The grow-out period was 90 days and the daily growth rate of *C. lazera* was 2.9 g/day.

In polyculture (*T. nilotica*: 200-300 fingerlings/100 m^2 + *C. lazera*. 10, 15, 20 and 100 fingerlings/100 m^2), with pigs (1 to 2 pigs per 100 m^2 of pond) and small quantities of brewery wastes and spoiled flour (directly fed to the fish in the pond), the average yield was 11.140 kg fish per ha/year (average of 4 trials).

If for socio-cultural reasons pig farming is not possible, the combination of chickens or ducks and fish is recommended.

3.3.2 Fish-cum-duck culture

Ducks are reared in pens over the ponds at a density of 1,000 to 1,500 ducklings/ha (10 to 15 per 100 m^2). Peking and Musocvy ducks are generally raised in Africa. The shelter where ducks are fed and spend the night is built over the pond on poles. The floor is made of lattice work to permit droppings and feed wastes to fall into the water. Under good conditions ducks reach 2 kg after 8 to 9 weeks. (Vincke, 1976). Peking ducks are preferred over Muskovy ducks since they stay on the water for much longer periods of the day than the Muskovy ducks. The ducks should be kept away from the dykes since they search for insects, frogs and snails, damaging the walls with their beaks and provoking erosion and the collapse of the dykes. Fencing inside the ponds is therefore recommended.

Ducks are known to eliminate almost all the snails in ponds in depths of up to 30-40 cm, thus controlling the intermediate hosts of bilharziasis.

In fish-cum-duck culture, ponds are stocked with tilapias, common carp or *Clarias lazera* at the rate of 2 to 3 fingerlings/m^2, without artificial feeding of the fish. Production can reach 2 500 to 4 500 kg fish per ha/year and 1 500 kg of duck per ha/year (Vincke, 1976).

In Zambia, using *T. Anderson ii* combined with Peking ducks, yields of 5 t fish per ha/year were obtained.

For large-scale extension of fish-cum-duck culture, a well-operated breeding and duckling distribution centre is needed. The production of ducklings is, of course, dependent upon the maintenance of an adequate brood stock (1 male to 4-6 females) of a selected strain. During one laying season, and under good conditions, a Peking duck will lay 120 to 160 eggs. During peak production, two eggs are laid every three days. One female duck will produce 70 to 80 one-day-old ducklings during a laying period of eight months under suitable conditions (Woynarovich, 1979).

3.3.3 Fish-cum-chicken culture

Chickens are reared in pens beside or over the ponds in roughly the same conditions as ducks, at a density of 10 to 30 chickens per 100 m^2 of ponds (1 000 - 3 000 chickens per ha).

It is estimated that one chicken produces about 40 g of excreta per day, or about 14-15 kg droppings/year and that a laying hen will produce enough manure to generate about 6-8 kg/year of fish biomass (Kassar, 1983).

Chicken culture is combined with polyculture of *T. nilotica* (2 fingerlings/m^2) and *Clarias lazera* (1 fingerling/m^2). One can also utilise common carp. After a rearing period of 4 to 5 months the production of fish can reach between 3 500 and 5 000 kg/ha/year (or 35 to 50 kg/year per m^2 of pond surface). At each harvest of the ponds, the production of chickens (live weight) is between 40 and 60 kg per 100 m^2 pond, depending on the number of chickens raised and the type of breeds used (Vincke, 1976).

The egg production (about 120 to 200 eggs/year per layer) can give a very interesting supplementary income.

3.4 Rice-cum-fish culture or rizipisciculture

Fish can be cultivated in association with irrigated rice culture. Rice will be the principal harvest and the fish production is considered as a complementary production.

Fish culture in rice fields is one of the best ways of using available aquatic resources in that additional protein production is obtained from irrigated rice areas (Coche, 1967). As a rule, the water in rice fields reaches a level of 5-25 cm. As the soil of the rice fields is highly fertile, the production of zoo and phytoplankton is high. These resources can be fully utilised by fish, thus converting into edible food what rice plants do not utilise (Vincke, 1979).

Since rice remains the main crop, fish culture has to be adapted to its requirements. Firstly it is essential to have complete control over the water and to provide drainage outlets in the rice fields. Secondly, one or more refuges must be made for the fish when the water level is lowered in the rice fields.

The species of fish to be used must be able to survive in shallow water, and to endure high water temperatures and low dissolved oxygen levels. Fish species should also be sedentary, have rapid growth and be able to withstand turbid water. Madagascar is the only country in Africa where rice-cum-fish culture is practised on a large scale, using common carp and some tilapias at stocking densities of about 2,500 fingerlings per ha (or 25/100 m^2 of rice field). The fish are harvested after a rearing period of about 120 - 140 days, and the yield is generally between 150 and 200 kg of fish per ha/year.

3.5 Fish culture in cages

Even if cage culture in rural areas is still practised on a pilot level, as in the Ivory Coast, cage culture is possible in almost all the small reservoirs and conservation dams built all over Africa during the last years.

Fish culture in cages and the conditions under which it is undertaken have been described by Coche (1976, 1977, 1978, 1979, 1982), Campbell (1978a, 1978b, 1983), Vincke *et al* (1981) and Balarin and Haller (1982).

Cage culture is a more sophisticated method than pond culture and can be practised on an artisanal level. Artisanal cage culture is more capital intensive than pond culture and good results, with economic returns, can only be obtained through intensive feeding (feed with protein content between 24-30%).

In rural areas, cages should be stocked with *T. nilotica* fingerlings, weighing at least 20 g each and harvested after 150 days of intensive culture. Fingerlings weighing 40 g on average can be harvested 30 days earlier. To maximise production and profit, high stocking densities of fingerlings are recommended, with a suggested initial biomass of about 20 kg/m^3. Experimental production in 1 m^3 cages ranged between 35 and 64 kg/m^3) in four months, with an average rearing mortality of 5.9%. Food conversion rates normally range around 2.0 with pelleted feed.

According to Campbell (1983) the main constraints for development of cage culture in the Ivory Coast have been the following:

(i) The lack of calibrated fingerlings, their availability throughout the year, at a normal price.

(ii) Availability of adequate pelleted feeds.

(iii) The occurrence of bacterial diseases at high stocking rates, especially in brackish water cage culture.

(iv) Marketing problems for large quantities of fresh fish (purchasing power of the consumers).

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THE ECONOMICS OF OYSTER CULTURE IN SIERRA LEONE

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1. INTRODUCTION

One of the major objectives outlined by the Sierra Leone Government is that of reducing food deficiency and the attainment of self-sufficiency in domestic food production. Meat and fish have provided the traditional sources of protein for most household diets. With the rapid inflationary rate that the economy is experiencing it is evident that fish and meat are fastly being priced out of the reach of most low-income earners. The inability of most low income households to purchase the required amounts of these traditional protein sources means that additional sources have to be encouraged or developed if the minimum protein requirements are to be satisfied in their diet. Oysters are rich in protein and usually serve as a good complement in enriching the household diet.

The rapid rate of increase of the population together with poor performance in the agricultural sector has exacerbated the food deficiency problem in the country. This has resulted in massive food imports to satisfy the food demands of the population. A consequence of the rapid population increase has been an increase in the demand for fish which (because of its relatively low price) has provided most protein requirements. Currently the bulk of the fish supplies is provided by marine fish with fresh water fish, aquaculturally produced products and imported tinned fish providing the rest of fish supplies.

Interest in aquaculture on a commercial scale is at its initial stages in Sierra Leone as is the case in most states in West Africa. Such enterprises are often constrained by lack of trained manpower, inadequate funds and a conspicuous absence of the most basic infrastructure. This is in contrast to the advanced industrialised countries where acquaculture products are generally regarded as luxury food items and the profit motive has provided the drive in most of these enterprising aquaculture business concerns.

In recent years, trawler fleet have accounted for the bulk of fish supplies. Estimated catch from trawlers is suspect due to the large quantities that are exported without the knowledge of customs officials. A not insignificant amount of fish supplies is from an estimated 12,000 artisanal fulltime and part-time fishermen operating about 6,000 canoes and estimated catch of 36,000 metric tons[1].

The numerous rivers and estuaries that are found in Sierra Leone provide an ideal breeding ground for the cultivation of wild oysters; among these the Sherbro, Rokel and Scarcies river are well known. Wild oysters are classified as mangrove oyster, rock oyster or mud oyster according to where they grow. Yields from mangrove oyster is low and of poorer quality, this being a consequence of exposure to heat, insufficient food and overcrowding on the aerial mangrove roots.

Serious consideration towards the large-scale production of oysters was pioneered by studies conducted by Golley-Morgan in 1964 examining the biology of mangrove and mud oysters around the Bonthe area.. Various difficulties encountered in this area made production economically non-viable. In 1973 there was a proposal for the current Oyster Culture Project to be jointly financed by the Sierra Leone government's Fisheries Division and the International Development and Research Centre (IDRC). The Oyster Culture Project was intended to take advantage of the availability of oysters in the numerous rivers and estuaries with the expressed purpose 'to increase the yield ... of mangrove oysters and to establish a practical and economic system for their cultivation through various culture systems, biological investigations, processing studies and sanitary and bacteriological surveys'.[2].

It is expected that the large-scale commercial production of oysters will have substantial benefits for both consumers and sellers. In the first place, oyster is usually part of the daily diet of most residents in the coastal areas. For most consumers in urban areas, oyster is used as a complement with fish or meat. Thus the development of better quality oyster would mean an enriched household diet and an improvement in nutritional standards. Furthermore additional income is created for these coastal and other rural inhabitants who usually sell the oysters in local markets. Sellers would also be assured of the required quantities they may need for sale at any time.

There is need and much scope for research on the market possibilities of establishing efficiently run large-scale enterprises involved in the cultivation of oysters. A research of this nature will involve the estimation of various elasticities which will give an indication of consumers' response to certain variables that are believed to be important decision-making variables in determining the quantity of oyster households will buy. This study will attempt to provide such assessments and make the necessary policy recommendations geared towards attaining government's objective. It is hoped that these policy recommendations would provide guidelines for public and private participation in a commercial cultivation of oysters.

2. BACKGROUND INFORMATION

Sierra Leone has an area of approximately 28,000 square miles and a population of about 3.5 million. A low lying coastline strewn by rivers and estuaries runs for about 340 km characterised by mangrove swamps. The country lies on the West African coast between latitudes 6°55′ and 10°N, and longitudes 10°16′ and 13°8′w. The continental shelf extends for approximately 20 miles to the South close to the Liberian border and approximately 40 miles to the north near the border with Guinea. Three major estuaries are found in the country; these are the Scarcies in the North, the Rokel river in the middle and the Sherbro in the South. The country experiences a tropical climate with a wet season running from May to October and a dry season from November to April.

3. OYSTER CULTURE METHODS

Experiments conducted on oyster culture by the Oyster Culture Project involved various techniques. These can be broadly classified under the suspended and bottom culture. Experience with bottom culture techniques revealed a high mortality rate of wild oysters caused by preying from other sea animals.

The suspended culture technique involves the rack culture; wooden trays; nets and plastic vexar mesh; mangrove roots with oysters attached and the raft culture. The results of these experiments disqualified wooden trays, nets and plastic vexar mesh and mangrove roots techniques for large-scale commercial production of oysters because of high cost, difficulties in producing large quantities and attack from predators. Two culture techniques that are worth further investigation are the rack culture technique and the raft culture. These have been adopted by the Oyster Culture Project and are known to have produced good results.

In most cases bamboo or mangrove trees are used in the construction of racks. There is a strong preference for using mangrove trees for rack construction since they are readily available in the construction areas and last longer. Straight posts with a 'Y' at one end are used as vertical posts. The straight ends are sunk about 1m into the earth allowing the Y-end of the post to remain at the surface. Two posts are driven along the shore, a straight pole fitted across the top vertical Y end of the pole and firmly tied or nailed to it. The strings are also nailed to the horizontal pole to avoid current drift. Each rack usually has about 150 - 200 strings of oysters suspending on it. A string of about 3.5m to 3.7m would normally yield about 5kg to 6kg weight of oyster which is about 90 to 115 oysters. Using average figures one can deduce an average yield of approximately 18.000 oysters per rack if this technique is employed.

Bamboo frames usually of 17′ x 17′ dimension are used to construct the rafts used in the raft culture technique. The separate pieces of bamboo are tied together with nylon ropes and an empty 44-gallon drum is tied to each of the four corners of the raft. A mixture of pitch and tar is used to paint the drums so that they can last longer. About 150 - 200 strings nailed on to the horizontal pole are draped over the raft. When the raft culture technique is employed a string of about comparable length with that used in the rack culture yields oysters of about 6kg to 8kg which is about 150 - 200 oysters per string. On average yields per raft, the raft technique is in the region of about 30.625 oysters.

4. COMPARATIVE COST-EFFECTIVENESS

We shall now attempt a cost-effectiveness analysis on both the raft and rack culture techniques in Oyster production. In the raft culture technique most of the items required for construction are of a semi-permanent or permanent nature. They are roughly classified as fixed costs since they would have to be maintained even if no oysters are cultivated. On the other hand the variable cost elements will include most of the costs incurred in processing the oysters.

The following table presents a breakdown of the costs incurred in production.

RAFT CULTURE TECHNIQUE

	FIXED COST (Le)	*Le. C*	*Le. C*
1.	Four 44-gallon drums at Le100 each	400.00	
2.	Cost of 200 strings per raft	50.00	
3.	Labour cost i) Assembly of frame		
	ii) Bamboo canes	42.00	
4.	Rope for anchor	10.00	
5.	Cost of tar	20.00	
6.	Depreciation charges	6.00	
			528.00

VARIABLE COST (Processing Cost)

i.	Firewood	50.00	
ii.	Plastic bags	4.00	
iii.	Salt	.40	
iv.	Other requirements (handtools, knives, etc.)	32.00	
			86.40
		Total Cost	614.40

Using the cost and output figure one is able to calculate unit costs of break-even prices per kilo.

Average yield of oysters per string = 7kg*. A raft has approximately 200 strings. This implies an average weight of 1400 kg yield per raft.

$$\text{Unit Cost} = \frac{614.40}{1400}$$

$$= \text{Le}0.45 = 45 \text{ cents per kilo}$$

An estimated 5 cents per kilo is used as mark-up for transportation charges.

If this is included in the unit cost the break-even price works out at 50 cents per kilo using the raft culture.

The rack culture technique on the other hand is less expensive than the raft culture technique. Most of the mangrove trees used to build the racks are readily available near the construction sites. This technique is more labour-intensive and as such labour charges are the dominant costs involved in the use of this technique. A break down of the construction cost will be helpful in making a comparative analysis.

Even though the raft culture technique is more expensive and involves higher unit cost it has the advantage of faster growth and better quality meat.

5. THE DEMAND FOR OYSTERS

The term 'demand' is often very loosely used reflecting the various disciplines under which the concept is examined. The demand for food quite often is used to describe nutritional requirements rather than demand in a strict economic sense. It is thus of importance to distinguish between the two concepts.

A country like Sierra Leone, which has an age distribution heavily skewed towards children would require more protein intake to meet the requirements dictated by rapid body growth and tissue replacement of the growing population - lack of sufficient protein or suitable

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* Yield here refers to meat yield i.e. $\frac{\text{Oyster meat wt.}}{\text{Whole oyster wt.}}$

proteins resulting in a deficiency of essential amino-acids, leads to a disease known as kwashiorkor which is fairly widespread in many Third World countries.

A notable trend which has been observed by several commentators[3] is the strong preference for diets rich in animal protein. The consequence of this is that there tends to be a strong positive correlation between sustained increases in income and the consumption of food derived from animal sources.

The most important source of animal protein is that of fish. It has been estimated approximately that 24,000 people are employed in small-scale fishing (linsenmeyer, [1974]), which has a number of distinct advantages over commercial fishing in terms of the employment generation and unit costs per investments compared to the rates of return to investments (Beck, [1989]).

The proportion of total expenditures spent on oyster consumption is relatively much smaller when compared to meat and fish. The survey found that in fact the mean value spent on oyster purchase per household was about Le3.31 which constitutes about 6 percentage of total food expenditure. Its demand could be considered as being *occasional* as distinct from being *basic*. The survey also found that oyster consumption tends to conform to certain socio-cultural consumption patterns. Oyster consumption tends largely to be urban oriented and is biased towards consumers in the middle and upper income classes. This would be expected.

6. ECONOMIC DEMAND ANALYSIS

The methodology employed in this study was the cross-sectional demand analysis. This technique of analysis focuses upon the demand by individual consuming units - households. For the purposes of this study, the household is defined as a group of persons who eat from the 'same' pot[4]. It is usual to include data on household expenditures, age-sex composition; plus those factors which are considered necessary to explain inter-household differences in expenditure patterns. Within the confines of Neo-Classical economic theory it is usually assumed that all households belong to an identified, well functioning, single market. This would imply that all households are faced with identical prices unless price differentials introduced principally due to transport costs. Hence prices are usually discarded in cross-sectional demand analysis.

In the survey conducted, it was adequately demonstrated that prices faced by consumers tend to be different in the different markets. In fact the standard deviation around mean prices (P) of oysters was estimated at 7.24 which is quite substantial.

This emphasises the fragmentary nature of the market in Freetown and provides justification for the inclusion of the price parameter in estimating the potential demand for oysters.

Household expenditure on food is used here as a proxy variable for household income. The difficulties in obtaining accurate figures for household income in less developed countries (LDC) cannot be over-emphasised.

The size of the household is also used as an explanatory variable in the demand model generated. It was observed that its net contribution is not quite significant since the relationship between household size and food expenditure is weak.

The cross-sectional data revealed that the multi-collinearity between the variables was low which enabled the researcher to obtain the relevant demand coefficients by the Ordinary Least Squares (OLS) method[5]. The household survey also provided estimates of expenditure elasticities on meat, fish and oysters.

The constant term (A) embodied both the biogenic and psychogenic factors determining the demand for these food items. The former includes factors such as age-sex composition of household whilst the latter, taste preference due to social class, ethnic patterns of demand and other psycho-sociological variables.

7. INTERPRETATION AND ANALYSES OF RESULTS

It must be admitted at the on-set that the use of the partial analyses method, which in this study centres around oyster demand behaviour in the Freetown area, introduces certain omissions as to the factors influencing household demand. This obviously imposes certain limitations in interpreting the empirical results obtained. Ideally, a complete systems demand model is required. However in practice, a trade-off must be made between the accuracy of the results and predictions and the danger of oversophistication of the model. In this vein, the estimations and projections based on this model should be viewed in terms of its delicacy in providing a framework for analysing the size of the market for oysters in the Freetown area which can be used for constructing a projection into the future demand for this commodity.

The regression run at the 1st stage level of specification of the model showed that the coefficients obtained was only significant at a 1% significance level. This is due to the small proportions spent on oyster consumption by households in the Freetown area. The R^{-2} is very low i.e. .12 which manifests the limited explanatory capability provided in the 1st stage level of specification of the model. The price elasticity at mean prices was estimated at .48, was insignificant using t-test analysis. Food expenditure elasticity showed very weak positive correlation at 0.25, this also proves statistically insignificant. The household elasticity at .46 is more revealing. It reflects the fact that on the whole, large families tend to consume more oysters as would be expected, also that there is some economies of scale in its consumption i.e. large household spend less per person on oysters relative to smaller households.

At the second-stage of specification, estimation yielded more statistically meaningful results. The R^{-2} was improved to .53 at 5% level of significance. The food expenditure elasticity estimated at 0.95 is negative which has economic validity implying that the share of expenditures on oysters fall as total food expenditures increase.

Comparison of estimated expenditure elasticities in other African consumption studies is difficult to make due to the specification of the model and commodity groupings.

It however favourably compares with King and Byerlee [1977] estimate of -0.93 for food in rural households in Sierra Leone and also the estimate of -1.27 for Eastern Nigeria by Hay [1966].

8. ESTIMATION OF THE CURRENT DOMESTIC MARKET FOR OYSTERS AND MARKET PROJECTION

8.1 Current Estimates

Using the budget share progression equation obtained for oyster expenditures and the mean values of the predictor variables, the current weekly budget share of oysters consumed can be computed.

$$\text{Ln } Qi + \ln P_i - \ln Ej = -\ 1.2768 + .4800 \ln P - .9476 \ln E + \dots + .4614 \ln Hs$$

The results show that roughly 6% of total food expenditures for households is spent on oysters.

Taking the number of households in the Freetown area at approximately 64,640 (Thomas 1973) and average household expenditures Le40.00 per month, the estimated market potential of oysters amounts approximately to Le1,861,600* pr 31 metric tons of oysters.

8.2 Projections

Market projections based on cross-sectional analyses are fraught with a host of intactable problems. In order to estimate this projection, use was made of the time series data showing oyster production. The assumption is made that the market provides the necessary absorbtive capacity.

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* *Ideally the demand and supply estimates must be equal. The prospect of this happening in real-life is remote. In the study the divergence is about Le1,714 which is regarded as not being very significant.*

TABLE 1
PRODUCTION LEVEL FOR BOTH WILD AND CULTURED OYSTER – (1979 – 1982)

(Whole Oysters)

YEAR	PRODUCTION
1979	18.3
1980	36.3
1981	19.0
1982	21.0

Source: Fisheries Division – Ministry of Agriculture and Natural Resources

The figures show the variation in the production of oysters. Since traditional methods yield roughly constant returns, the fluctuation is mainly due to cultured oysters. Apart from the sharp increase in 1980, one can discern a slightly increasing trend in its production.

Holding 1982 as the base year the following demographic and macro-economic projections were made on the assumption that the average annual growth rates remain constant.

TABLE 2
DEMOGRAPHIC/MACRO-ECONOMIC PROJECTIONS

Population (millions)	1982 (BASE YEAR)	1984	1986	1988	1990	Average annual growth rate (%)
Total	3.356	3.533	3.719	3.915	4.121	2.6
Urban	0.839	0.943	1.059	1.190	1.337	6.0
Rural	2.517	2.624	2.735	2.851	2.972	2.1
(Freetown)	0.474	.543	.623	.711	.814	6.0
Persons per household						
Total	8.4	8.4	8.4	8.4	8.4	–
Gross Domestic Product (GDP) Le(m)	1,264.5	1,305.3	1,347.4	1,390.9	1,435.7	1.6
Gross Domestic Product (GDP) per capital (Le)	376.8	384.4	392.1	400.1	408.0	–1

The curve shows that in all likelihood, the production which would equate demand for oysters must be in the neighbourhood of 50 metric tons. This is held ceteris-paribus that all other factors remaining the same especially the price differentials between oysters and the other traditional protein sources.

9. POLICY RECOMMENDATIONS AND CONCLUSION

The principal aim of this study is that of assessing the size of the domestic market provided by the Freetown area for oysters and make a tentative projection as to future demand. In order to promote the establishment of economically viable large scale production of oysters as envisaged in the oyster culture project, it is necessary to assess the absorbtive capacity of the market with a view to observing salient constraints.

The study shows that there is a sizeable domestic market for oysters which could enable production to attain scale economies. The present estimate of 31 metric tons of oysters to meet consumer demand and the projection of roughly 50 metric tons by the end of the decade adequately manifests the size of this potential market.

There are a host of problems however which must be tackled in order to attain these economies.

The first problem is that of coping with the perishability of oysters. In the survey it was estimated that processed oysters without preservatives or storage go bad in roughly 48 hours. This imposes a considerable constraint on sellers willingness to procure large stocks of this product. Research is necessary to enquire into the possibility of improving storage. For instance, oysters can be preserved in a brine solution, however this might not meet the taste requirements of consumers. It would also be necessary to provide refrigerated vehicles which would dramatically cut down the problems of perishability.

The second problem is that of distribution and sales. The present method appears most unsatisfactory since oysters are usually sold in the evenings around Krootown Road market. Attempts must be made in diversifying selling locations so that a wider market can be catered for.

Given the profitability of oyster culturing, the private sector must be provided the necessary incentives to go into this line of production. The expanded scale of production would not only serve the domestic market but also the export market. This would involve some amount of quality control and assured distribution outlets. In this vein, a concerted promotional campaign must be mounted which could serve to attract private investors. Technical assistance could be requested from international organisations such as the IDRC to help in the establishment of this venture.

In order to circumvent protectionist measures in industrial markets, recourse must be made in exploring the trade possibilities of exporting under the aegis of the Mano River Union or ECOWAS, to neighbouring West African countries.

It is the considered opinion of the author therefore that oyster culturing offers tremendous opportunities for Sierra Leone.

NOTES

1. Due to the paucity of data on estimated catch the figure represents a conservative estimate based partly on the demand for fish which has an estimated elasticity of 0.9.

2. Quoted from the terms of reference in the establishment of the Oyster Culture Project funded by the International Development Research Centre (IDRC).

3. See for instance, W J Thomas (ed.) The Demand for Food, Manchester University Press, 1972 especially chapter 2 by J M Currie also L Goreux: Income and Food Consumption, FAO, Monthly Bulletin of Agricultural Economics and Statistics, Vol. IX No. 10, October, 1960 et. al.

4. This definition tends to be widely used in household studies in many developing countries. This reflects the extended family system found in most of these countries. It also avoids to some extent the semantics involved in obtaining a definition of the household which conforms to its sociological, psychological and economic aspects.

5. This is in consonance with the views expressed by Massell (1969) which assumes that consumption and production decisions are independent. This is due to the insignificant levels of auto-consumption in the food items studied.

   Le 1 = £0.36

AQUACULTURE IN NIGERIA

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1. INTRODUCTION

The concept of fish farming is recent in Nigeria. With the establishment of Government pilot schemes, and an extension service in many states of the country, the practice is receiving more attention. At present, about 12.5 million ha of water surface area are being utilised for different types of culture in Nigeria. There is approximately 1 million ha of mangrove swamps in the coastal areas, of which a large proportion could be developed into brackish water systems.

Olayide *et al* (1973) have reported the average protein intake in Nigeria as 63.24 g/Caput/day. This is below the FAO estimated minimum requirement of 70g/Caput/day, of which 35g/Caput/day should be of animal origin.

The amount of fresh and frozen fish in the diet of Nigerians is increasing, particularly with the reduction of the cattle populations in the Sahelian region - the traditional source of animal protein in Nigeria (Mabawonku 1980), due to the effects of drought. Similarly, Awachie (1974) reported that fish consumption accounts for over 40% of animal protein in Nigerian diets.

According to the National Fisheries Development Committee (NFDC) report (1982), the effective demand for fish in Nigeria as estimated for 1980 was 1.5 million metric tonnes with a projected increase above 2.3 million metric tonnes by 1985. However the current effective annual total fish supply in the country was 800,000 tonnes in the same year, out of which 510,000 tonnes was produced locally. The balance of 300,000 tonnes was supplied from fish imports, in forms of frozen, canned and stockfish. In view of the large deficit in fish supply, there appears therefore an urgent need to increase the intensification of fish production in Nigeria.

With the reduction in catch from inshore fisheries due to over-exploitation of most commercial marine species and the increased costs of offshore fishing, the development of aquaculture would be a logical and effective method of boosting domestic fish production in Nigeria.

According to Pillay (1968), the coastal areas of Nigeria comprise of brackish water mangrove swamps; and approximately 1 million ha of these swampland is available in the Delta regions for large scale brackish water fish culture. The potentials for aquacultural development in such areas become enormous, and may be used to increase natural fish production through fish farming as practised in the Asian countries where two-thirds of the world's fish production is recorded (Wokoma and Ezenwa 1982).

Unlike the crop production subsector of agriculture, the fishing industry has expanded rapidly over the last two decades, particularly the domestic fish production. (Waniboko 1982). It was observed that between 1964 and 1979 there was an approximate ten-fold rise in fish production from 58,000 tonnes in Nigeria, while the domestic supply has increased from 20% to 70% of total; with a future prospect of further expansion through aquaculture.

This review therefore attempts to highlight the enormous scope for large scale development of fresh and brackish water fish farming, particularly in land-locked States in the villages where land is more readily available in Nigeria.

2. PRESENT LEVEL OF AQUACULTURE DEVELOPMENT

Although FAO (1957) reported that fish culture has been in operation in tropical Africa since 1924, in Kenya where trials with *Tilapia spp* were carried out, the practices of modern aquaculture is still a new concept in Nigeria.

However, the construction of the Panyam fish farm for 'Tilapia' production in 1944 marked the inception of fish culture in Nigeria (NFDC 1979). Demonstration fish ponds and commercial fish farms have been established over two decades ago, during which a series of government pilot schemes were set up from 1950, to raise local fish species in Okigwe, Ibadan and Ikoyi, Lagos. (1971). After the nationwide campaign of 'grow your own fish' in 1964 there seem to have been a remarkable increase in the number of fish farms in the country, notably: government fish farms at Baguda (Kano State), Funtua (Kaduna State), Etinam (Cross River State) and Benin (Bendel State). Community-owned fish farms were also sited at Onitsha, Ijebu-Ode, Oyo and Sokoto for extensive culture of *Tilapia spp, Clarias spp, Chrysichthys spp* and Cyprinus carpio.

However, recent estimates by Dada (1975) show that there are more than 2,000 fish ponds occupying a total area of over 1,000 hectares, situated all over the country.

A few hatchery and breeding centres have also been developed by some States' Fisheries Division and private farmers for accelerated fingerling production.

Aquaculture is just gaining prominence in Nigeria. Presently, its level of development and rate of growth is rather slow. Out of about 0.8 million ha of swampland in the six coastal States – Ondo, Ogun, Bendel, Lagos, Rivers and Cross Rivers; only about 27 ha (0.003%) is being utilised for fish farming. (Ajana 1980). The slow growth of aquacultural practices in Nigeria could be attributed to the basic problems of poor knowledge of the biology of local fish species and their culture. In addition there has been a lack of capital to set up fish farm projects.

Grover *et al* (1980) reported that aquaculture could succeed in Nigeria in view of the existing biological potentials; while Afinowi (1975) revealed that a total of 1,521,000 ha of water surface area was available for aquacultural development. Also PRC (1982) estimated a yield of between 3.5 t/ha/yr from fish farms, in Nigeria. From this estimate it would therefore be possible to obtain a potential fish production of up to 4.5 million metric tonnes from the total water surface area if effectively utilised for aquaculture.

3. AQUACULTURE FACILITIES

Ajayi and Talabi (1984) found that of the estimated total area of perennial water swamps and brackish water available in Nigeria, a considerable proportion of these possess desirable characteristics for aquaculture in terms of water supply, soil type, topography, access, tides etc.

A survey of inland waters in Nigeria revealed that aquaculture is practiced in various holding facilities such as ponds, lakes, reservoirs, river barrages and flood plains, with a total water surface area of about 12.5 million ha and a potential yield of 2.3 million metric tonnes per year (Table 1 and Table 2).

4. FISH PONDS

Modern aquaculture development in Nigeria is geared towards the use of earthen ponds for fish culture. The ponds are constructed with one to four-diked impoundments holding water at average depths of 1.5m to 2m; and are of two major types.

The first type of ponds are water-shed or single-dike barrage ponds constructed on the lower part of a valley where only one wall is built across the stream.

The second type are contour ponds with quadruple-dikes constructed on even surface land. The excavated soil is used to build the embankments for holding water. Sources of water supply to these ponds are basically from surface run-offs, pumping of water and tidal flow, controlled by means of monks and sluices.

A total of about 2000 fish ponds have been recorded in Nigeria, with an estimated surface area of 5,416 ha capable of producing up to 11,000 t/yr. (Afinowi 1975; Ita and Sado 1983).

Similarly, the Federal Department of Fisheries is developing 50 ha of fish farm at Tiga (Kano State), while there are some modern fish farms located at Oluponna (Oyo State); Ikene (Ogun State); Makurdi (Borno State); Wuya (Niger State) and Umuna Okigwe (Imo State) to enhance fish production through aquaculture. Each of the farms is estimated to have a capacity to produce about 2.5t/ha/yr. (NFDC 1982).

5. FISH CULTURE SYSTEMS

Recent studies reveal that the major established government pilot schemes in Nigeria such as the Pamyam fish farm, Agodi fish farm, Ikoyi fish farms (NIOMR) and Okigwe fish farms are mostly contour ponds.

However, most community and private-owned fish farms are of the barrage pond type often integrated with other forms of agricultural production. A few private fish farms have been equipped with modern recirculation systems operated under intensive farming conditions.

Although aquaculture appears to be an outstanding way of increasing fish production, particularly where harvest from the wild is limited; the amount of fish yield would depend on the degree of control exerted over the culture environment. Three major types of fish culture systems are distinguished in Nigeria presently:

(a) Extensive fish culture
(b) Semi-intensive fish culture
(c) Intensive fish culture

The extensive method of fish farming involves little or no control over the culture environment and the fish obtain all their food from the natural habitat as typified by the Ilesha Government fish farm in Oyo State, the Government fish farm at Okuo in Bendel State and private fish farms under integrated agricultural schemes. While the extensive fish farms may occupy more land, fish production in relation to the pond size is always low.

The semi-intensive method of fish culture as practised in Nigeria entails low level of supplemental feeding often with fertilisation of the ponds in addition to food from natural sources.

Fish culture systems utilising little space and water with high stocking density are managed intensively with regular adequate supply of supplementary feeds. A typical intensively managed fish farm in Bendel State has a production capacity for 5,600 tonnes/ha/year, where the stocked fish depend solely on artificial feeding. However the desirability of more economic use of water, together with a requirement for more environmental control has increasingly tended towards a more careful use of water. The intensive fish culture using a re-circulated water system tends to solve the problem of fish culture where water becomes a limiting factor.

In enhancing the development of aquacultural practice in Nigeria, a model fish farm comprising of five ponds with sizes ranging from 0.04 ha to 0.08 ha was constructed by the Department of Wildlife and Fisheries Management, University of Ibadan for training and research within the framework of a commercial enterprise.

Similarly Dada (1975), reported that there are few hatcheries and breeding centres in Nigeria for rearing fish seeds which are distributed to Government and private fish ponds at subsidised rates. Although indoor tanks are available, they are mostly used for research purposes.

6. FISH SPECIES USED FOR AQUACULTURE

Fish species for aquaculture are selected on the basis of their good performance under controlled conditions. Both indigenous and proven exotic species have been used for culture in Nigeria. (Table 3).

7. FISH FEED DEVELOPMENT

Although aquaculture is fast developing in Nigeria, the yields obtained from fish farms are still low. The low yield has been attributed to inadequate supply of balanced fish diets. At the moment, only a few institutions are engaged in fish feed manufacturing in the country, and it is still not possible to meet large scale demand for feeds.

However there is a large potential of feed ingredients from local plant and animal sources which are capable of supplying the nutritive requirements of fish.

Nutrition experiments on the production of balanced rations to meet the quantitative requirements of indigenous fish species are in progress in some research institutes and universities.

8. CONCLUSION

As demonstrated by the government's emphasis on forestry and crop production programmes in educational institutions, aquacultural practices should be intensified throughout all stages of educational curricula in the country. Fisheries research institutions should intensify their efforts in solving problems associated with local aquaculture production. Such problems to be looked into include those of fry production, fish feed requirements, feed formulation from local ingredients and the management practices required for economic rearing of desired fish species.

At community level, prospective fish farmers will benefit from research findings from the aquaculture industry if adequate information is made available through government extension agents. Similarly, the bank guidelines for obtaining loans to meet the initial capital requirement for establishing and developing a viable fish farm should be widely circulated. The role of extension services in creating a 'national' fish farming industry in Nigeria therefore becomes invaluable.

TABLE 1

ESTIMATES OF POTENTIAL FISH YIELD FROM ALL AVAILABLE INLAND WATER RESOURCES

Types of Water Body	*Estimated Surface Area (ha)*	*Expected Yield per ha (per year)*	*Potential annual Yield per ha (*Mt/year)*
Reservoirs			
(a) Large reservoirs	250,387.0	60 kg	15,023.22
(b) Small reservoirs	25,146.91	100 kg	2,514.79
			17,538.79
Rivers			
(a) Flood ponds	1,650.0	100 kg	165.0
(b) Main course	10,812,410.18	20 kg	2,164,316.20
(c) Flood plain	515,000.0	50 kg	25,750.0
(d) Stagnant pools of seasonal rivers	200,000.0	20 kg	4,000.0
			2,194,231.20
Major lakes	677,000.0	100 kg	67,700.0
Fish ponds	5,476.06	2000 kg	10,952.12
Miscellaneous Waterbodies			
(a) Cattle ponds	638.50	100 kg	63.85
(b) Burrow pits	2.0	100 kg	0.20
(c) Mining paddocks	106.0	100 kg	10.60
			74.65
TOTAL YIELD	12,487,817.65		2,290,495.98

N.B. *Mt/year = Metric tonnes per year
source: Ita & Sado (1983)

TABLE 2

WATER SURFACE AREA OF FISH PONDS AND FLOOD/CATTLE PONDS IN THE NINETEEN STATES OF NIGERIA IN DISCENDING ORDER OF MAGNITUDE (WITH EMPHASIS ON EXISTING FISH PONDS)

States	*FISHPONDS*				
	Existing (ha)	*Proposed (ha)*	*Under constuction*	*Flood/Cattle ponds (ha)*	*Total Water Surface (ha)*
Plateau	471.0	Nil	Nil		471.0
Oyo	448.58	33.0	Nil		295.40
Sokoto	195.40	100.0	Nil		295.40
Bendel	130.0	247.0	15.0		392.40
Imo	123.27	1.50	10.22		131.99
Kano	94.21	Nil	Nil	63.0	157.21
Benue	87.50	600.0	200.0		887.50
Ondo	84.19	549.96	2.06		636.21
Rivers	61.91	1029.25	499.58		1587.74
Anambra	55.66	Nil	Nil	1650.0	1705.66
Cross River	51.40	9.30	20.0		80.70
Ogun	48.15	39.0	46.0		133.15
Borno	24.70	Nil	Nil		24.70
Kwara	22.09	8.50	3.50		34.09
Bauchi	15.0	Nil	Nil	15.50	30.50
Kaduna	14.0	Nil	Nil	560.0	574.0
Lagos	13.43	10.0	Nil		23.43
Niger	4.70	70.0	40.0		114.70
Gongola	Nil	Nil	Nil		Nil
TOTAL	1,945.19	2,697.51	836.36	2,288.50	7,761.56

Source: Ita & Sado (1983)

TABLE 3

SOME CHARACTERISTICS OF ACCEPTABLE SPECIES IN NIGERIA

Species	*Acceptability by consumers*	*Seed availability*	*FeedingHabits*	*Salinity tolerance*	*Remarks*
Tilapia spp. *T. nilotica* *T. galilea*	Fair	Throughout all seasons.	Phytoplankton algae, detritus. Accepts supplementary feeds.	0-26%	Tolerant to wide ranges of temperature and salinity. Problem of prolific breeding.
**Chrysichthys spp.*	Very good	All seasons but obtained from wild sources and inadequate.	Mostly bivalves. Accepts supplementary feeds.	0-26%	Hardy and thrives well under polyculture with *Tilapia spp.* and *Mugil spp.*
**Clarias spp.*	Very good	All year round from the wild and artificial breeding but inadequate.	Worms and detritus. Accepts supplementary feeds.	0-10%	Very hardy. Tolerates muddy water. Recommended for polyculture with *Tilapia spp.*
**Mugil spp.*	Good	Throughout the year, obtained from wild sources.	Phytoplankton, algae, detritus.	0-35%	Performs well in brackish water. Trials in fresh water under way.
**Heteritisniloticus*	Fair	Seasonal (rainy season). Inadequate.	Phytoplankton and Zooplankton.	Fresh water only.	Fast growing; small sizes preferred.
**Macrobrachium spp.*	Very good	Seasonal wild sources and breeding programmes.	Detritus	0-10%	Abundantly distributed in certain areas.
**Cyprinus carpio* (Exotic)	Very good	Through artificial breeding. Inadequate.	Omnivore, and readily accepts supplementary rations.	Fresh water	Performs well in fertilized ponds, highly supplemented with feeds.

* Studies underway on their Biology and performance under culture conditions

Source: Ezenwa 1979

TABLE 4

ANNUAL COST AND RETURNS FOR A ONE HECTARE FISH FARM UNDER POLYCULTURE

Ground Area : 1.5 ha
Product Area : 1.0 ha

Capital Cost

	₦	K	S	2
Land at ₦900/ha	1350	00	1755	00
Survey at ₦500/ha	500	00	650	00
Clearing at ₦600/ha	600	00	780	00
Construction equipment	400	00	520	00
Labour for Excavation and Embankment	4000	00	5200	00
Shed	1600	00	2080	00
Nets	950	00	1235	00
Contingencies	300	00	390	00
Total Capital Cost	9700	00	12610	00
1. *Expenditure*				
Interest at 9% per annum and depreciation at 10% per annum for ₦9700.00 ($12,610.00)	1843	00	2395	90
2. *Operating Cost*				
Fingerlings (including transportation)				
– Tilapia 1000 fingerlings at 25k each	250	00	325	00
- Carp (*Cyprinus* sp) 5000 fingerlings at 50k each	2500	00	3250	00
– Catfish/Mullet 5000 fingerlings at 50k each	2500	00	3250	00
Fertilizer (N:P:K) applied at 30kg/ha/month for 10 months	60	00	78	00
Lime	32	00	41	60
Feed for 320 days – 2 tons at ₦1200/ton	2400	00	3120	00
Labour at ₦216/month for 12 months	2592	00	3369	60
Contingencies	346	00	449	80
Total	12523	00	16279	90

Returns	₦	K	$	
Tilapia 520kg/ha/year at N3.00/kg	1,560	00	2,028	00
Carp 2500 kg/ha/year at N4.00/kg	10,000	00	13,000	00
Catfish/Mullet 1800kg/ha/year at N4.00/kg	7,200	00	9,360	00
Total Revenue	18,760	00	24,388	00

Profit

₦18,760 – 12,523.00 = ₦6,237.00
$24,388 – 16,279.90 = $8,108.10

Rate of Return on Operating Cost = 49.8%

Currency Conversion: ₦1 = $1.3

Source: from Survey 1983

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AQUACULTURE IN DEVELOPMENT PLANNING

AQUACULTURE DEVELOPMENT AND PLANNING

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1. INTRODUCTION

Although aquaculture practices have prevailed at various levels of technology in different countries, and the technical aspects have received much attention, planning at the national level has received very little attention. The potential aquaculture offers for contributing to rural and national economies is being increasingly realized, but a well-planned national strategy and coordinated action is necessary if aquaculture is to develop at a reasonable pace.

The nature and extent of government involvement in aquaculture development depends on its existing status and the availability of financial and technical resources, and would normally conform to the government's overall socio-economic and political policies. For economic reasons, financial provisions and services for aquaculture are generally made in conjunction with those of the fishery and agriculture sectors.

Government involvement normally includes surveys of the national resources, collection and analysis of data required for developing a well-planned strategy for aquaculture, as well as providing much of the infrastructure requirements, and various support services such as research, training, extension, information, financing and credit incentives, and statutory rights.

2. THE ROLE OF AQUACULTURE

The role that aquaculture will play in the rural and national economies need to be ascertained for planning purposes. Aquaculture can be practised for a variety of purposes, including food production, improvement of stocks in natural waters or sport fishing, but the main purpose is generally the production of human food. Government policies may determine the amount of emphasis on production of cheap fish for the populace, in relation to production of highly priced fish, shellfish and other aquaculture products for the luxury market or export. Aquaculture may be seen as a means of creating yet another avenue for employment. It also may be a means of utilising land that has little or no other use.

Aquaculture has certainly been proved to contribute significantly to the rural economy in many countries. 'For the individual farmers, productivity is the foundation that can provide him with a reasonable standard of living, and for the nation, productivity is the basis for ensuring consumer food products at reasonable prices. By improving the physical well-being and quality of life of the poor, their productivity and ability to contribute to the national economy may be enhanced' (Gerhardson, 1979).

Aquaculture, agriculture, horticulture and animal husbandry can be practised together to yield increased income to the rural farmer. For example, farming of rice with fish, ducks with fish or pigs with fish is being profitably practised in several countries. While the ponds serve as water reservoirs the areas adjoining the ponds can be used for cultivation of crops such as sweet potatoes, cassava, yams and various fruit trees. Aquaculture therefore fits well into integrated rural development programmes.

A factor to be considered is that initial investment and operating costs of the subsistence level or small production units of the rural farmer is likely to be minimal, with family members contributing the labour required.

Depending on the status of aquaculture development in the country, the development plan also needs to take into consideration the existing or potential large-scale aquaculture enterprises in the private or public sector, and the nature and extent of support that need to be given to them.

Owing to the existence of many intermediate types of operations, it is difficult to categorise aquaculture systems into small-scale and large-scale industrial operations. 'However, broad categorisation of the planning requirements are possible, and although the details of the strategy may vary there are some general guidelines to be followed in each type of operation' (Pillay 1974).

3. BASIC DATA REQUIRED FOR PLANNING

Essential pre-requisites for planning aquaculture development are basic data which will help to determine the existing level, extent, and potential for aquaculture development, projections of national requirements through aquaculture and species and culture systems that are most suited to the prevailing climatic conditions and local preferences.

Pillay (1974) lists them as follows: estimates of total requirements for domestic consumption or export; existing and possible sources of production; estimates of possible yields from natural stocks; estimates of yields through viable aquaculture, taking into account possible socio-economic benefits to rural areas, including new avenues of rural employment; and improvement of the diet and nutrition of the people.

The choice of the species and culture sytems will depend on whether it is for local consumption or export, local climatic conditions, particularly temperature range. The culture of indigenous fish is generally preferred, for local consumption, but for this data on the general biology and life cycle of the locally available culturable species is required. The need for introducing species, if any, with adequate precautions, has to be determined.

Data is needed on the extent and locations of areas suitable for aquaculture, as well as on the quality and productivity of the waters that will be utilised. It is known that many aquaculture ventures have failed due to their being wrongly sited. Data on the biology and pathology of the species projected for culture will help to determine the suitability of culturing them in the selected environments.

Among the other data required will be the availability of inputs such as fertilisers and feeds and locally available agro byproducts that could serve as feed ingredients, including estimations of quantities and costs.

The categories and respective numbers of existing trained manpower including extension personnel, will be necessary. So also would data on the available support services to the fishery and agriculture sector which may be utilised in an aquaculture development programme.

Finally, there should be a socio-economic study in order to determine the benefits that will accrue to the target communities through aquaculture development.

4. LEVEL OF GOVERNMENT ASSISTANCE

The nature and extent of government assistance to aquaculture will depend on the current status of aquaculture in the country, projected plans for further development, the size of the communities involved, the already existing or projected services in related sectors and the available financial resources. Government involvement will normally conform to the overall political, social and economic development programmes of the country.

5. LEVELS OF AQUACULTURE DEVELOPMENT

Farm sizes range from subsistence level units to commercial scale enterprises, from a fraction of a hectare to more than a thousand hectares and operated by private individuals, private or government cooperatives or private companies.

Farming systems are often referred to as being 'extensive', 'semi-intensive' or 'intensive'. In 'extensive' systems low stocking rates and yields per unit area are involved, and capital, recurrent technological and management requirements are not relatively high. Commercial scale ventures normally involve large areas in order to ensure profitability. On the other hand very high or intensive stocking rates and yields per unit area are involved in 'intensive' culture systems. Here the aim is to achieve profitability using relatively small areas of advanced technology and high management skills. While extensive farming may be considered to be labour intensive, intensive systems involve mechanisation of certain operations in order to minimize dependency on labour. Intermediate between the two are various 'semi-intensive' culture systems.

In planning aquaculture development the role aquaculture can play in generating opportunities for employment, improvement of the rural economy and potential for foreign exchange savings on imports or earnings on exports may be given due consideration, besides the overall objective of increased food production.

6. FEASIBILITY STUDIES AND PILOT SCALE OPERATIONS

Aquaculture development plans, whether for integration into rural development programmes or for large-scale commercial ventures need to be based on feasibility studies and pilot scale operations, particularly if new technologies are to be introduced. The latter will help also to test the assumptions on which the introduction of a particular technology is based.

7. MANPOWER REQUIREMENTS

A pre-requisite for the successful implementation of aquaculture programmes is the availability of adequate expertise and trained personnel.

Aquaculture development plans therefore include an estimate of the national requirements of trained personnel at the various levels. This entails training of personnel and whether training arrangements should be made on a permanent or temporary basis. Three main categories of technical persons are generally needed. One is the 'aquaculturist' who has university level or equivalent education and who will be responsible for the execution of all technical aspects of the programme. The other is the 'technician' whose specialized training in selected areas will enable him to assist in activities such as hatchery operations or certain routine analysis in the laboratory relevant to the programme. Third category is the 'extension worker', whose training will enable him to transfer technical knowledge to the farmer, and also to win his confidence, respect and friendship.

This last category may not be specially recruited for aquaculture, but may be drawn from other sectors such as fisheries or agriculture, and given the necessary training in aquaculture. Besides these three categories, specialists in other areas such as aquaculture engineering, fish nutrition and marketing may be required, but these could also be drawn from related sectors.

With regard to training, it may be more economical to have the aquaculturists trained at regional level, or other existing institutions, than to establish training facilities for them. Training of technicians and extension workers could be carried out within the country, and the aquaculturists need to play an important role in this.

8. SUPPORT SERVICES

Success in implementation of a plan for aquaculture development will depend to a considerable extent on availability of the necessary support services, which have to be provided mainly by government. Among them are research, training, extension, information arrangements and finance and credit.

National research programmes are necessary for solving problems related to aquaculture under local conditions. These would also include pilot scale trials to test the technical and economic feasibility of new technologies. Besides biological and technical problems, research should also be carried out into socio-economic problems associated with aquaculture.

Research related services to the farmer, whether at the subsistence or commercial level, includes assistance in determining the suitability of sites for aquaculture, improved pond management techniques, fish feed formulations using inexpensive locally available by-products, simple processing techniques for aquaculture products, prevention and cure of diseases and monitoring of the aquatic environment for pollution control.

The success of an aquaculture development programme will depend very much on a well organised extension service. Extension services should be the link between the research centres and pilot farms on the one hand, and fish farmers on the other. The technical competence of extension personnel coupled with gaining the respect and confidence of the farmer is very important, especially in rural development programmes. The plans for extension services should also include facilities such as transport, audio-visual aids and necessary funds to enable the extension worker to carry out his task effectively.

Related to research as well as extension is dissemination of information, which need to be included in the plans. These include extension pamphlets, field manuals, and film strips for the benefit of the farmer. Provision should be made for collection and review of aquaculture information and statistics from aquaculture ventures within the country. A more comprehensive arrangement for collection, storage and retrieval of aquaculture information will be computer based. It may be economical to have it at the regional rather than the national level.

Financing and credit for aquaculture enterprises may have to be arranged from agricultural development or cooperative banks or other existing credit organisations. In this context, the difficulties of the rural farmer in providing collaterals need to be given consideration. Hitherto in Africa and other regions very little agricultural credit has been made available to the smallholder farmers. In order to ensure its proper utilisation, credit to fish farmers should best be linked to the extension services.

Besides credit, government assistance will be required to ensure timely supplies of fish seed, for which hatcheries are needed together with fertilisers, chemicals and drugs for sanitation, weed and disease control.

Support services for marketing, storage and processing are not normally required for subsistence level farming, but may have to be planned for. Fish farmers normally market their products directly to the consumer or through existing distribution channels. As production increases, existing sales organisation in the fishery or agriculture sector may have to be utilised, or even separate organisations may have to be created for aquaculture products. Plans for aquaculture production may also cover the areas of product quality, eg, special cleaning procedures for oysters, and regular inspections and certification of products by pathologists.

9. LEGAL MEASURES

While subsistence level farming does not appear to face serious legal problems, provisions need to be made to accord legal rights to aquaculture entrepreneurs, including the right to acquire or use various sites in the sea and other common water bodies for aquaculture, since conflicting uses may be involved. Regulations need also to be provided concerning the discharge of pollutants into aquaculture areas, fish diseases, inspection of and certification of aquaculture products, minimum saleable sizes of fish and shell fish used for or produced through aquaculture vis a vis regulations pertaining to minimum sizes in captive fisheries, and the introduction of exotic species.

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THE LOGISTICS OF FISH FARM PROJECT APPRAISAL

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1. INTRODUCTION

At the most recent CIFA meeting in Egypt, in an appraisal of the status of aquaculture in Africa, Coche (1982) sums up the situation by stating: 'Most of the failures of aquaculture development programmes in Africa so far can be explained by the lack of qualified technicians and of an adequate infrastructure, as well as by the absence of a government policy specifically aimed at this form of development.' The lack of a well organised aquaculture extension service - that indispensible link between producer, researcher and administrator - was therefore considered a consequence of the general scarcity of specialised trained personnel and was contributing to low development especially of small-scale rural projects.

Aquaculture planning, either government policy, through extension services to the project in the field at village level or by private investment, is a vital component to ensure successful development. Ill conceived projects and a contradiction in objectives were highlighted by the FAO Workshop held in Accra.

These objectives are clearly different. On the one hand planning must consider subsistence farmers totally dependant upon Government inputs, on the other, totally self-sufficient commercial projects either state run or private enterprise. Whereas the objectives may be different the logistic steps which determine the feasibility and degree of intensification are not. The outlined logistics pathway as developed by a private consultancy firm in Kenya (Balarin, 1981), have been modified as applied to a recent FAO survey (Balarin, 1984 a-g, 1985a-e).

2. LOGISTICS IN AQUACULTURE DEVELOPMENT

This section summarises the logical steps in the sequence in which they need to be considered in aquaculture development project planning. The details of each section are elaborated upon below:

Primarily fish farming is a means of food production, therefore at the onset the national food budget needs to be examined to determine present nutrition level and the scope for crop or livestock production to meet demand. Protein requirement to sustain the population growth needs to be considered and the role fish could play in satisfying that demand, identified. Fishery resources would provide a certain portion depending upon the size of the excess requirement so a priority rating could be placed on alternative means of increasing fish production, ie. aquaculture.

Once it has been determined that a market will exist for farm fish then a potential fish farming zonation map can be created. Initially such a zonation would be related to water temperatures in terms of species choice, system type and degree of intensification. Other environmental factors, and in particular climate, water resources, topography and soils type ultimately decide the suitability of a site. At this stage established aquaculture practices need to be examined to assess the past performance, learn from the mistakes made and to identify those practices which have been unsuccessful and are worthy of further consideration.

The first feature of existing developments is to look at species choice. To determine which of those in common use, either indigenous or exotics, are the better adapted or whether further species introduction needs to be considered. Species selection is generally founded on certain bioeconomic and biotechnical criteria.

Having identified suitable sites and species choice, it is necessary to examine systems options. This concerns the socio-economic factors such as the skills and available technology in country as well as scope for integration, availability of inputs either feeds or fertiliser, extension and training services and the source of funds to develop the project. The final analysis concerns the economics of the operation, the benefits to the nation or investor and examines whether national infrastructure could support the plans of the formulated project.

3. DEMOGRAPHY AND FISH REQUIREMENT

Before considering a fish farm venture it is necessary to first identify whether there is a need to increase fish protein, quantify demand and identify areas which would benefit the most.

3.1. Population Growth

The population, annual growth rate for most of Africa ranges between 2.0% (Upper Volta) to 4.2% (Mozambique) which implies that by the turn of the century countries will have between 33-75% more people to feed. Further statistics provided by UNICEF (Grant, 1984) imply that in 1981 food production relative to 1971, averaged between 6 5% (Somalia) to 142% (Libya). The implications are that food production has not kept pace with demand. It would therefore be necessary to examine the development potential of crop and livestock production, identify the scope of government policy to meet the need and quantify the likely contribution of fish protein to achieve a balance nutritional budget. This can be considered at a national level or localised to village or regional requirements.

3.2 Fish Protein Requirement

Undoubtedly areas most remote from existing fishery resources will have the greatest demand and possibly the highest market price for fish. Such areas could benefit from the increased protein and prices may make commercial activities attractive.

In any instance, an average normal daily protein requirement [DPR] is given as 64g/ind/dy and it is considered optimum that fish provide at least 5% of this i.e. about l0 kg fish/ind/yr. Knowing population growth it is possible to predict future optimum national fish requirements.

3.3 Fishery Resources

Fishery resources now need to be examined and an estimate arrived at for the potential maximum sustainable yield +MSY]. The current status of fishery development, development plans and the scope for realising the MSY would indicate the capacity for expansion and give an estimation of the likely contribution to the nutritional budget. The difference would show the scope for fish farming. Of the 41 countries considered by Anon [1984] just under 50% had below optimum fish consumption levels. In particular Niger, Upper Volta, Ethiopia, Rwanda, Somalia and Sudan consume less than 2 kg/ind/yr. The scope for increased fishery production in these countries is limited, therefore aquaculture would appear a logical solution.

4. ENVIRONMENT SUITABILITY

Once it has been determined that a nation or area could benefit from aquaculture it is now possible to begin to examine site options. In this case climate, water resource and geography play an important role. Water temperature especially is perhaps the single most important factor determining species choice and site productivity.

4.1 Climatology:

The climatic history of a site is important not only to determine likely prevailing conditions but to forecast the chance of a severe condition such as drought, flood or hurricane.

4.1.1 Temperature:

Fish are cold blooded hence their performance is directly related to water temperatures. The optimum range for growth in tilapia is 22°-32°C, carp 10°-30°C and trout 5°-18°C. Temperatures either side of this range could adversely affect productivity within the tolerance range of the species. Conversely fish have a 'Q10' of about 2.5 such that for every 10°C temperature rise within optimum limits, growth increases by a factor of 2.5. Ideally therefore fish farms should best be situated nearer the upper limits of optimum. As is common in agriculture it is therefore possible to also calculate for fish the growth season as the number of 'degree days' above minimum requirement [i.e. 18°-20°C for Tilapia] and arrive at the likely length of the growing period.

Water temperatures are generally 2°-5°C below the mean annual air temperature and suitable zonation can be predicted from temperature isohyets [Table 1]. It must be borne in mind that air temperatures decrease by 0.4°-0.8°C for every 100m increase in altitude. Water temperature is correspondingly lower and it is possible to predict fish yields with relation to altitude e.g. Tilapia in ponds at sea level could potentially yield 5 - 6t/ha/yr decreasing by 250-300kg for every 100m increase in altitude to a maximum of 2000m which is beyond the natural range of the tilapia [Coche and Balarin, 1982; Cross *et al*, 1983].

4.1.2 Rainfall, Sunshine, Evaporation:

Rainfall will determine the available runoff for water supply to a fish farm. Regions of perennial rainfall, of long dry spells or arid conditions would need to derive water from a permanent source. Areas exposed to near all year round rains could feasibly sustain rain fed ponds. The area of catchment being related to runoff and pond volume as in Ethiopia in a rainfall region of 1400-1800 mm/yr rainfed ponds would require a catchment of 100ha per hectare of pond [Gamachu, 1977] to maintain a constant water level.

Rainfall intensity would also affect intensive operations. Persistent rain would reduce the work day and decrease the chance of feeding a pelleted food which must be kept in dry storage. Likewise, less intensive pond production could also be affected for cloud cover would reduce photosynthesis, lowering primary productivity and could thus create deoxygenated conditions in densely stocked ponds.

Evaporation represents a water loss from the system and in warm, low altitude zones could represent a substantial water loss from ponds. Evaporation rates rangin from 1500 - 2400 mm/yr in a pond of 1.0ha would represent a constant flow of 1.7 - 2.7m^3/hr required to 'top-up' the evaporation loss. Cross *et al* (1983) offer an even higher requirement of 3.6m^3/hr. Rainfall will undoubtably reduce this requirement but does not represent a constant replacement and in the dry season there will be a net loss.

4.1.3 Humidity, Wind:

These features are likely to influence evaporation losses, but more important, in hot humid environments if any form of artificial feed is to be used, there is a need to guard against fungal moulds developing and producing aflatoxins [e.g. *Aspergillosis flavin*]. In addition humid conditions could induce rancidity in stored foods and generally an expected maximum shelf life in a well ventilated store is not more than 30 days.

Winds can play a role in ventilating ponds. Wind induced wave action can enhance oxygenation. However it is not entirely beneficial to orientate the pond axis, parallel to the prevailing winds. Resultant wave action would erode banks but even more serious would be the mixing of bottom layers during severe storms resulting in deoxygenation of the main body of water especially during seasonal 'overturn'.

4.2 Hydrology and Limnology

Water availability naturally is the ultimate deciding factor in site selection and systems choice. For intensive tank culture this represents a constant flow requirement of about 8 - 10m^3/hr/t [or 70,000 - 90 000m^3/t/yr] [Balarin and Haller, 1982] and for ponds between 30,000 - 40 000m^3/t/yr [Pruginin and Arad, 1977] and 7.8m^3/hr/t [or 60,000m^3/t/yr] [Cross *et al,* 1983].

4.2.1 Water Resource

If the water source available were either lake or ocean then the only scope for utilising it would be either floating cages or pens or possibly by abstraction to onshore units. Pens, enclosures or acadja systems would be suited to shallow water bodies while cages would vary in design according to exposure of site but all system types would be dependant upon water currents determining oxygen supply and deciding stocking rates. Man made dams, rivers or streams hold potential for diversion to supply water by gravity to land based units. Eliminating pumping costs in this way make this option highly attractive for application to smallholder farms as well as commercial operations. It is important however to have at least 1% slope for gravity channel flow so that ponds could be created below the water table but this represents additional problems of management and harvesting. Wells and boreholes are not to be recommended for fish farmers unless shallow, or integrated with irrigation.

If pumping is necessary, it is essential to minimise the total head for high volume, low pressure irrigation pumps operate at the greatest efficiency below a 5m head. Abstraction by animal power is equally limited to a shallow lift and where situations permit natural flooding could be exploited as in the howash system in Egypt [Balarin, 1985a].

4.2.2 Water Quality

Temperature has been mentioned in section 4.1.1. Oxygen levels are a feature of management and not necessarily of consideration in project planning unless abstraction is from ground water or from below the thermocline and therefore low in oxygen. Aeration must be considered. Salinity is a feature of species choice and tolerance range. For a euryhyline fish such as tilapia which is noted to live from 0 - 120ppt, drastic salinity changes are unlikely to affect production. However in onshore, tidal prawn ponds attention needs to be paid so that salinity does not rise during the dry season due to evaporation loss and that in wet seasons, freshwater runoff does not enter ponds creating dilute conditions.

Perhaps one of the important features of waters in Africa, is that if fish farm units derive water from rivers it is a common feature that turbidity increases during seasonal floods. Turbidity due to suspended solids therefore would reduce primary productivity and create siltation problems in ponds. If colloidal, turbidity could persist such that classical sedimentation traps would be ineffective. In intensive systems turbid waters could be damaging to gills and prevent proper management and feeding as the fish are not visible. If such waters are used, abstraction during floods should be controlled.

Of the other parameters such as pH, alkalinity and hardness generally, pond waters need to be slightly alkaline [pH 7 - 8]. Acid waters would need liming. Other nutrients although important can be controlled by manure or fertiliser application and are of little consequence in site selection except for toxic elements. Metals such as ferric hydroxides are rare but need to be considered especially near mineral deposits where there is every chance of a potential soluble fish poison. Similarly, water sources receiving effluents from urban or industrial areas could carry toxic pollutants and it is wise first to survey a river course before siting a pond to evaluate the 'goings-on' upstream.

4.3 Physical Geography

Relief is important in the siting of a fish farm for the terrain must be of a gradient sufficient to ensure water flow by gravity but not such that construction costs are prohibitive.

4.3.1 Soils

Stony or rocky ground would perhaps be ideal for tank or raceway units. Ponds however need a substrata that should contain clay proportion liable to create an impermeable layer as well as maintain sufficient cohesion to retain structural integrity on a 1:2 slope characteristic of pond dykes. Cross et al [1983] gives an account of clay soils and considers that kaolinite must be at least 20% of mineral content to build stable, permanent ponds. Acceptable seepage losses are considered as 5-10mm/dy and in a 1ha pond would require a 'top-up' rate of 2.1 - 4.2m^3/hr representing a further need for water. Sodic, saline or acidic soils should be avoided. Agricultural land use and soils maps should be consulted to help identify potentially suitable soils.

4.3.2 Topography

The importance of altitude has been discussed in section 4.1.1. therefore of concern here is the suitability of slope for economic pond development with minimum earth movement. In smallholder units which are not likely to be more than 100 - 500m^2 it is possible that a steeper slope [i.e. 5%] is acceptable but for larger estate ponds of 1 - 5ha the gradient should not be more than 1 - 2%. Slope is therefore important in design.

4.3.3 Vegetation

Agroecological regions would indicate those areas where fish farming is likely to compete with potentially arable agricultural land. It is important that this does not occur and that fish farm developments are restricted to suitable sites but on marginal or near marginal areas [i.e. waterlogged] in order to avoid possible conflict in farmer interests. Vegetation cover is also important for if construction is on adjacent swamps, marsh or mangrove, organic detritus would be high in the soils and vegetation clearing an expensive process. Likewise areas in dense bush or forest would be equally costly to prepare. Further, areas of forest such as over river banks may have a cooling influence on the water supply and create a micro-climate suited to a particular species. However in the long term, deforestation for fuel wood or building materials can not only result in an increase in temperature but contribute to erosion and increased siltation, a feature now affecting trout farms in Kenya [Agius and Balarin, 1982].

4.3.4 Erosion Risks

Erosion problems can cause pond siltation. Cross et al [1983] considers a permissable erosion soil loss to be 10t/ha/yr in sand and 12.5t/ha/yr in clay soils. In rainfed ponds the catchment required [see Section 4.1.2.] would imply an annual deposition of 1000 - 1250t/ha or 10 - 12% of pond volume unless erosion is prevented or siltation traps incorporated in design.

5. PUBLIC HEALTH AND LEGISLATION

Whereas fish farm production produces a food benefit there are also risks involved in terms of human health hazards.

5.1 Water Borne Health Hazards

Schistosomiasis is perhaps the most prevalent debilitating disease problem in Africa with a 70 - 90% incidence. The hosts of this snail borne vector can find ideal conditions in fish ponds and screening, regular cleaning, drying and lime application or the use of mollusci-sides or a polyculture with snail eating fish is to be encouraged as well as proper sanitation near the ponds and water source. Malaria and river blindness may also be a problem but it is likely that the fish will control the larvae of the host mosquito or black fly and only water channels may be breeding sites.

Fish parasites, such as Heterophyiids are pathogenic to man, can infect fish in ponds if snail vector are present. Control is as for bilharzia as well as to ensure fish are thoroughly well cooked before consumption.

5.2 Legal Aspects

Aquaculture as a novel concept in food production is not protected by law in most African states, even traditional fishery laws do not apply. In fact legislation governing water abstraction, river pollution, health, fish handling and water or coastal/lakeshore rights all hinder development especially for smallholders. There is a need to formalise the process for lease of suitable sites, obtaining exploitation and marketing licences, rights to use water as well as legal protection of aquaculture projects against theft. Control of river pollution by farm effluents is necessary though perhaps not as deliterious as industrial effluents.

Large scale farmers can obtain protective insurance against accidental loss. Similar safeguards for smallholders should be considered.

6. AQUACULTURE DEVELOPMENT

Past and present status of national aquaculture projects should be indicative of the fate of previous attempts and an analysis of failures and success suggestive of likely future trends.

6.1 Status of Fish Farming

If there has been a past history of failure in fish farm projects, it may not be wise to consider rehabilitation of these projects without appreciating the reasons for abandonment. A critical analysis of the historical statistics of development is necessary. Regions where fish farming has been a success highlighted and an inventory created of public and private sector projects. A correlation of achievements and results with inputs, systems and/or species type, zonations, etc. should help pinpoint those areas requiring future attention. From the above environmental parameters it is possible to predict theoretical likely fish farm zonation options. This should now be verified by actual results available from the field and a more accurate potential fish farm zonation map created for future planning.

6.2 Aquaculture Resources

Existing fish farm infrastructure, the species in use, other potential indigenous species, exotics already in country, and those which could be considered for transplanting should all be tabulated as well as in-house technology from original pioneer research results. Given this information it is possible now to develop a rationale as to how to proceed, all the while considering the information available in the literature. If there is no in-house expertise qualified to develop a rational appraisal of the scope for development, external expertise or consultants should be considered.

7. SPECIES SELECTION

In Africa there are about 25 species which are actively cultured, of which the tilapia are the most common with 10 species featuring prominantly in village pond culture. There are however a number of considerations which must be kept in mind during species selection.

7.1 Biological Criteria

The optimum environmental requirements of a species for maximum growth must be matched up to the prevailing environmental condition and a potential zonation arrived at. Should local species not be considered suitable for a particular zone, introductions should be considered. Large parts of Africa are above an altitude where temperatures are not suitable for tilapia and for those reason carp [*Cyprinus carpio*] has been widely transplanted as it is more cold tolerant. Generally however *Oreochromis niloticus* [or an all male hybrid] is recognised as the most favourable species but other candidates include Chinese carp, African catfishes, freshwater prawn and mangrove oysters.

7.2 Biotechnological Criteria

Historically tilapia have been farmed in Africa, therefore the technology is widely known and well documented with over 3500 references, [Balarin and Hatton, 1979]. For most other African fish species the technology in-house is not at a level where the species could be reliably farmed. Research efforts however are underway and could benefit those nations' adjacent to a pioneering source. A transfer of technology however would be necessary. On the other hand isolated commercial trout and prawn farms have developed for the economics of producing an up-market product, which justify the high technical cost.

7.3 Bioeconomical Criteria

The following considerations not only secure the economic viability of a project but are of an important psychology to small-scale farmers implying maximum benefit for minimum input.

Growth Rate: rapid levels achieving market size in the shortest period under local conditions i.e. 6 - 9 months for a 250 - 300g fish.

Food Conversion: the fish should be able to effectively convert low grade protein into high quality flesh at the lowest FCR.

Genetic Capacity: not only must the fish be able to reproduce easily in captivity but have genetic characteristics suited to the market, i.e. colour, shape, texture, taste, etc.

All these factors are of prime importance in marginal zones, for fish generally are very low priced therefore the selection must be for maximum efficiency to derive greatest benefit.

7.4 Pathological Criteria

Wild populations of fish would act as a reservoir of pathogens which will be likely to infect farm fish. Farm hygiene and management to minimise stress is important. A hardy resilient fish [such as tilapia] needs to be considered for small scale projects where minimum diagnostic and treatment facilities would be available. Similarly large scale projects need to pay attention to site location to guard against persistent localised disease infections, a feature which has caused the need to transfer a large tilapia cage culture project in Ivory Coast. Alternatively costly prophylactics or water treatment needs to be considered.

8. SYSTEMS SELECTION

Table 1 considers possible process options and compatible species choice depending upon site temperature regime. More intensive system types are suitable only in areas where all year round production is possible. However there are a number of socioeconomic factors to consider.

8.1 Manpower Quality

When considering the introduction of fish farming for the first time at village level, the target should be either traditional livestock farmers or ones with fishery background, for these people are likely to appreciate the necessary fishery husbandry. Techniques would be simple subsistence pond culture with the objective of training to achieve semi-intensive status. The benefits of introducing fish culture should be clearly stated and not exaggerated beyond expectation.

Governments need to consider whether existing training facilities are adequate both for farmers and extension agents. This is perhaps the first step to any successful development. To attract a suitable calibre of extension trainee, social and remunerative benefits would have to be attractive to function as an incentive.

8.2 Technological and Financial Assistance

Small scale fish farmers depend primarily on expert services: extension, and public or cooperative credit. It is important that well trained technical extension assistants are placed in the field and provided with some form of mobility [i.e. bicycles, motorcycles or car]. These agents need good backup services in the form of research and fish farming centres for demonstration and source of seed, as well as equipped for disease diagnosis.

8.3 Availability of Inputs

The state of agriculture and agro-industries need to be examined. Crop and livestock zonation will indicate likely sources of by-products which could be used for feeding or fertilising ponds. Other crop wastes from cottage processing industries such as rice or maize bran, cassava peels, beer residues etc. all have a value as supplemental feeds. For more intensive production residues such as oil seeds, cakes, wheat middlings or brans, brewery wastes, slaughter house wastes and sugar processing by-products - are all available.

Livestock husbandry would yield manures as a by-product. Generally used on crops as a fertiliser, manures could find similar application in ponds to enhance primary production. Integrated fish and livestock offers perhaps the most economic form of fish production. Potential yields in t/ha/yr for the following density per hectare of pond are: pigs [70 - 100/ha] = 5 - 10; ducks [1000 - 2000/ha] = 4 - 8; chickens [1000 - 1200/ha] = 3.5 - 7 and geese [500 - 800/ha] = 2 - 3. Balarin [1984] also considers the scope for integration with irrigation projects where 0.2 - 2.5t/ha/yr of fish and a 5 - 15% increase in rice is possible in riziphisciculture. Irrigation storage dams also represent a potential fish production of 17 - 190kg/ha of crop irrigation.

8.4 Economics and Marketing

The status of the national economy will play a deciding factor in fish farm development. If the national economy is poor, state funds are unlikely to be available and any foreign aid would not be channelled to fish farming as generally this sector is low priority, a feature which may have to be reconsidered in the future.

If commercial ventures, private or government, are feasible it is important to survey the market to determine prime species consumer acceptance size and preferred process. Generally, fresh fish are favoured thus refrigerated storage is necessary. Often it may not be possible to select a production site near a prime market, it is important therefore in economic analysis to evaluate the benefits of enhanced growth from suitable environmental conditions versus crop value and transport cost to distant markets. It is also feasible that conditions may favour an export market i.e. cheap labour and favourable climate in Africa produce inexpensive products which could fetch premium prices on a foreign market or earn valuable foreign exchange.

9. NATIONAL INFRASTRUCTURE

Finally, the state of development of a nation can influence the degree of efficiency of operation. Electricity supply could facilitate pumping but if not available on site the cost of installation or use of fuel for pumping can be prohibitive. Similarly if a site is remote, roads would have to be built to facilitate extension and delivery of suppliers and in larger units for transport of product to market. If there is an already established industry or agriculture such as at village level, no additional construction is required other than production units but there is need to add an extension centre. Larger commercial projects need to be self-sufficient with breeding and production units as well as administration, domestic and storage buildings. There is scope to consider at village level that a division of labour is possible i.e. a collective group concentrate on the hatchery, another on fattening, a third marketing, etc. The industrial development of an area is also important from the point of mechanical support services and spares especially relevant to large scale projects.

TABLE 1 TENTATIVE FISH FARM ZONATION PATTERNS IN AFRICA

LOCATION	ALTITUDE	AIR TEMPERATURE		POTENTIAL FISH SPECIES AND SYSTEM CHOICE					
				COLD WATER (eg. Trout)		TEMPERATE (eg. Carp)		WARM WATER (Eg. Tilapia	
		Minimum	Maximum	GP [a]	System [b]	GP [a]	System [b]	GP	System
A. Coastal/Lowlands	0- 600	21	34	–	–	12	1-4	12	1-4
B. Midlands	600-1200	17	30	–	–	12	1-4	9-10 (summer)	1-3
C. Highlands	1200-2000	12	25	3-6 (winter)	3-4	10-12	1-4	3-6 marginal	1-2
D. Uplands/Mountain	Above 2000	8	20	11-12	1-4	3-6	1-2	–	–

[a] GP = Potential Growing Period in Months

[b] System Types 1 = Natural Occurring (Lake/Dam/River/Sea)
2 = Ponds
3 = Cages, Pens or Closures
4 = Tanks or Raceways

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RESEARCH IN AQUACULTURE

AQUACULTURE RESEARCH IN AFRICA

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1. INTRODUCTION

Aquaculture Research conducted in Africa and elsewhere has resulted in the identification of a small number of species as potentially important and efforts are directed towards development of suitable technologies for their culture. Research has been directed towards culture of tilapia by controlling overpopulation through cage culture, sex-direction and mono-sex culture, genetic selection and selective breeding and on integrating with agriculture and live-stock systems. Simple techniques of breeding and seed production are available for difficult-to-spawn species but are yet to reach target users, namely village level fish farmers in many countries. Non-availability of seed of economically important species in many aquaculture centres is still a major problem. The Regional and sub-regional centres of aquaculture organised by the Aquaculture Development and Coordination Programme of the Food and Agriculture Organisation of the United Nations has initiated several research and training programmes. Collaboration of the national aquaculture research centres with well established institutions and Universities will accelerate progress in scientific research on local aquaculture problems as well as involvement of modern technologies. This will also help in the quicker dissemination of research findings and exchange of technologies in the region.

2. AQUACULTURE RESEARCH IN AFRICA

The FAO/UNDP workshop on Aquaculture Planning in Africa and the FAO/CIFA Symposium on Aquaculture in Africa, both held in 1975 in Accra, were the two concerted efforts that looked into the status of aquaculture in Africa as a whole. While the former took note of the aquaculture requirements for two decades ahead, the latter reviewed the status of technology available in the scientific management of aquaculture.

In most countries in Africa the mainstay of aquaculture in the past has been small-scale fish farming in domestic ponds, integrated in many cases with rural development programmes.

As a result of the various regional workshops and symposia held in 1975/76 the strategy accepted for worldwide development of aquaculture, aimed at achieving a major increase in production in the next two decades included (a) the selection of a small number of aquafarming systems as against a variety of species and culture systems being experimented with (b) wider application of the selected farming systems and the promotion of greater investment to achieve sizable increases in production (c) organisation of appropriate assistance for the formulation of sound investment projects based on feasibility studies of pilot projects and (d) provision of support services in the form of applied research to facilitate technology transfer and improvement of techniques. According to Arrignon (1982) aquaculture in Africa is subject to considerable risks due to lack of information and knowledge on hydrobiology, ichthyology, zootechniques as well as problems of sociological aspects. The lack of technical know-how and financial constraints in development of aquaculture in Africa were also recognised decades earlier.

2.1 World tilapia production through aquaculture

Some thirty years ago world production of tilapia through aquaculture was around 20,000 tonnes. This has increased to 200,000 tonnes by 1983 of which four Asian countries alone (Taiwan, Indonesia, Thailand and Philippines) accounted for 180,000 tonnes. Taking this trend into account it is now projected that an annual world tilapia production of 2,000,000 tonnes is feasible.

2.1.1 Comparison with other livestock and agricultural products

Through genetic and technological improvements in the last thirty years, and while the poultry and pork industries have increased by a factor of 2 and the new improved Asian rice (IRS) varieties have a potential factor of 10, tilapia in the same time period has improved in potential productivity by a factor of 100! (ICLARM, 1984).

2.2 Species utilised and available for aquaculture in Africa

The most important fish that are being cultivated in Africa at various levels are the Tilapias. Tilapias are well known for their hardiness, good growth rate, adaptability to supplemental and artificial feeding with a wide range of feeds, tolerance to wide fluctuations in physicochemical parameters, pond breeding habit and local acceptability as a good quality fish. Bardach *et al* (1972) have suggested 14 species of Tilapia as important from a fish culture point of view, while Balarin and Hatton (1979) listed 23 species of *Tilapia* and *Sarotherodon* that have been tried in aquaculture. Though there are several species of tilapias available, it is now generally accepted that the following species have the most potential and are economically important ones. These include *Oreochromis niloticus, O. mossambicus, O. aurea, O. macrochir, O. andersonii, O. esculentus, O. spilurus niger, T. rendalli, T. guineensis, T. zillii, Sarotherodon melanotheron* and *S. galilaeus. While the first seven are material mouth brooders and the three species of tilapia substrate spawners with semi-adhesive eggs and a greater fecundity, S. melanotheron* which has a distribution in West African Coastal areas is a paternal mouth brooder, whilst *S. galilaeus* is a biparental mouth brooder. In addition to this there are several other species of tilapias that are economically important in certain localities as a capture fisheries item from open water or being used in small-scale domestic fish farming.

However, in most of the fish culture attempts with tilapia, the major problem encountered has been the early maturation and breeding of the species in short periods leading to overcrowding in the ponds and very low levels of production of market sized fish. It was this trend, coupled with several other factors that led to the lack of interest among aquaculturists, particularly among small-scale fish farmers in Africa. However, in recent times, particularly in the last decade there was a general awakening of interest in aquaculture particularly because of demonstrations of simple technologies that led to profitable production of fish through small-scale as well as large scale farming systems. These farming systems developed as a result of carrying out research on several aspects of applied values particularly on the control of over-population and stunting in tilapia culture.

3. MONO-SEX (ALL MALE) CULTURE

It is known that males among tilapia grow faster than females and that when all males are stocked in a pond, reproduction and overcrowding could be overcome. Hence considerable work has been carried out on the development of this technique either through physical segregation of the sexes or through modification of the sex by hormone treatment.

3.1 Mono-sex culture by differentiation of sexes

The better growth rate among males is regarded as a genetic factor and not associated with reproductive processes. However this growth superiority could be modified by environmental factors (Fryer and Iles, 1972). The technique includes manual sexing of tilapia based on several characteristics. The technique has been tried in several countries in Africa as well as outside. (Guerrero and Garcia 1983, Lovshin and DaSilva 1975). Manual sexing is laborious and needs some skill. In addition to this, females which constitute some 50% are wasted. Clear identification of sex is possible in fishes of around 50g. It is reported that a person could segregate about 2,000 males per working day. However, the accuracy of this is not guaranteed. Use of mechanical graders to separate larger sized males also has been tried in some countries (Bard *et al* 1976) but the accuracy of this method also is not assured.

Sex-segregation by observing secondary sexual characters and sexual dimorphism is also possible among tilapias. Differential coloration among males and females at breeding time is a characteristic phenomenon. It is observed that the pelvic fins among males reach far beyond the anal and genital openings posteriorly while among females it is short and do not reach anywhere near the anal and genital openings. At Buguma (ARAC, Port Harcourt) following this criterion sexes could be successfully segregated among *T. guineensis* and *S. melanotheron*. However, in mono-sex culture of all males in *S. melanotheron*, manual segregation results in the occurrence of fry in ponds since the species is a paternal mouth brooder and many adults will be carrying eggs in their mouths.

3.2 All-Male hybrid culture

Several inter-species crosses among tilapias have resulted in 100% or higher all-male hybrids. The all-male crosses include *O. mossambicus* × *O. hornorum*, *O. niloticus* × *O. hornorum*, *O. niloticus* × *O. macrochir*, *O. niloticus* × *O. aureus*, *O. niloticus* × *O. variabilis* and *O. spilurus niger* × *O. hornorum* (Hulata *et al* 1981, 1983), Pullin and McConnel 1982).

The system has given some positive results and is now being practised in several parts of the world. However, many centres are finding it difficult to maintain separately the different species and strains. Wohlfarth and Hulata (1983) have reviewed the applied genetics of tilapias and its role in aquaculture.

3.3 Genetic improvement in tilapia and production potential

In South East Asia, culture of *O. mossambicus* alone in the 1950s has given a yield of 2.5 t/ha/yr with a growth of 140 g/yr. By the 1970s this production rate had improved to 60 t/ha/yr and a growth rate of 700 g/yr with hybrids of *O. mossambicus x O. niloticus*. In the 1980s, the production of red tilapia (*O. niloticus* x albino *O. mossambicus*) has led to the very high production of 600 t/ha/yr and a growth of 1,000 g/yr. It is now expected that tilapia yields of 600 - 800 t/ha/yr could be attained through genetic research coupled with intensive farming technology (ICLARM 1984).

3.4 Sex-direction and all male culture

The principle underlined here is that before sex differentiation in tilapia (which is immediately after yolk absorption and when the fry is about 9 - 12mm in length) the fry are fed with ethyltestosterone or methyltestosterone along with feed at 30 to 40mg/kg of feed fed at 4% body weight for 3 weeks. This resulted in 98 - 100% male offspring. It was found that the hormone treated fish had a fast growth rate and that the system had the advantage of reducing reproduction, with females not being wasted, and higher yields due to faster growth rate and a higher stock density. However, some of the points raised against this technique are the requirements of technological skill for effective treatment, increase in overall cost of fry production and possible side effects to man and fish by the drug. Since there is a considerable time lapse between treatment and consumption of fish the hormones would have been metabolised completely by the time the fish is consumed.

3.5 Cage culture

Culture of tilapias in cages is reported to eliminate the problem of breeding and over-population. Even when breeding takes place, the eggs are either not fertilised or are passed through the mesh and hence no production of fry. However, unlike hormone treated all males, in this system considerable amount of energy is utilised in the maturation and gonadal development which in turn means wastage. In recent years cage culture of tilapias has been attempted on a commercial scale in Ivory Coast, the Philippines and other countries (Campbell 1978, Coche 1982, Coche 1983, Guerrero 1979, Pagan 1975).

In most of the countries, tilapia cage culture is carried out on an experimental and small scale basis except in Ivory Coast, Costa Rica, Puerto Rico and Philippines where commercial scale cage culture of tilapia is practiced. According to ADCP (1978 and 1980) there is a definite potential for Tilapia cage culture in lakes and rivers in Latin America and Africa, both on commercial and subsistence levels. The size of cages varies for different culture systems and the level of technology available. According to Coche (1982) at experimental stages and at subsistence levels, generally, cages should not exceed a few cubic metres. However, he recommends medium sized cages (6 to 20m^3) to be used at artisanal levels, while larger cages of 50 - 100m^3 could be used at industrial levels.

The maximum carrying capacity for a cage depends on the mesh size, cage size, type of fish and level of dissolved O_2 in water. For 1m^3 cages the recommended safe limit is about 73kg and it is known that as the size of the cage increases the maximum carrying capacity decreases. In Ivory Coast a production of over 70kg/m^3 cages is reported.

3.5.1 Research requirements

A review on the research requirements for Tilapia cage culture (Anon 1979) has identified further research and standardisation of cage material which could present less fouling and toxicity problems, layout and positioning. In Latin America (ADCP 1978) and in Africa (ADCP

1980) cage culture has been identified as a priority culture system in the Research programme of the FAO/UNDP Regional Aquaculture Centres.

In rural areas where facilities are available, like rivers, brackishwater, lakes etc. cage culture opens up ample opportunities at individual entrepreneur level or at co-operative level.

Small scale tilapia cage culture projects carried out in two fishing villages in the Philippines indicated that the household income of participating families increased from P6183 to P41768 per year and household savings from zero to P7102 per day. The participating families consequently purchased gear for sustenance fishing and luxury foods for their households (Gonzales 1984, P14.00 - US$1.00). However in addition to mobilising the required funding, procurement of equipment and locally available materials and identifying indigenous potential species it will be necessary to import training and guidance, at least initially. In addition to this, feed requirement has to be taken into account and preferably locally available raw materials should be utilised.

3.6 Use of predator to control over-population

Stocking predator fish in Tilapia ponds to control overpopulation is an age-old practice and has been tried in most parts of Africa and elsewhere. In Thailand using *Clarias sp*, and *Ophiocephalus* as predators in *O. mossambicus* ponds a production of 17.8 ton/ha/yr has been obtained. In Africa, production up to 5 ton/ha/yr in tilapia culture has been reported by using predators like *Lates niloticus, Clarias sp, Bagrus* etc. In Africa, the most common predators available are *Lates niloticus, Clarias lazera, Bagrus sp, Micropterus salomides* (introduced), *Hemichromis fasciatus*, etc. In many cases, predator-prey ratios have been worked out and satisfactory production is reported. A ratio of 1 : 10 for *C. Lazera* and *O. niloticus*, 1 : 20 and 1 : 84 for *L. niloticus* and *O. niloticus* and other combinations also have been reported (Guerrero 1982).

Though relatively larger sized tilapias and good production are obtained through use of the predators, the problem of availability of required numbers of fry of suitable sizes at the proper time and lack of well-tested standardised predator-prey ratios among others, have limited the use of this technique.

3.7 Tilapia breeding and seed production

Considerable work has been carried out on this aspect in tilapia which included stocking density brood fish, spawning frequency, male - female ratios, breeding behaviour, incubation and fry rearing, feed requirements of spawners and fry. For large-scale fry production in tilapia two systems are now being practiced (1) land based hatchery and (2) lake-based hatchery. While in the former fry production is being carried out on land in the confinement of a hatchery, in the latter breeding and seed production is practised in nylon hapas fixed in marginal areas of a lake or reservoir. Fry production figures given by different authors for different systems vary considerably. Further fry production is also influenced by several factors like size and age of brooders, season, water quality, type of feed available, species, etc. Stocking densities for brood fish suggested are 5,000 brood fish/ha (Guerrero 1983) and 100 - 200kg brood fish/ha (Boussard *et al*, 1983). Fry production figures reported include 880 fry/m^2/month using cage spawning (Guerrero 1979), 4.2 fry/m^2 in ponds using supplemental feeding (Campbell 1978) and 3 fry/m^2/ month in 350m^2 pond (Lovshin 1982). A sex ratio of 1 : 3 and 1 : 5 (male to female) for O. niloticus & O. aureus) has been reported by many to give excellent fry production. According to Boussard et al (1983) large scale fry production using the open pond system is simple and suited for developing countries. The technology is simple and can easily be adapted by large and small scale fish farmers.

4. CULTURE AND BREEDING OF *CLARIAS LAZERA*

Clarias lazera is another African species that meets various aquaculture requirements which includes fast growth rate, quick adaption to various types of artificial feeds and adjustability to adverse environmental conditions. Even a growth rate of about 5g/day has been reported for this species. The species has been successfully cultivated in the Central African Republic, Arab Republic of Egypt , Cameroon, Ivory Coast and several other countries. Suitable breeding techniques have been developed under controlled conditions. However, there is a considerable amount of work to be carried out on larval and fry rearing in the hatchery and nursery ponds so as to obtain high rates of survival. This is one of the species that holds considerable prospects for cultivation as mono-culture or in combination with other species like tilapia.

Among other species that are presently being cultivated and which need much more research work to be carried out include *Chrysichthys nigrodigitatus, Bagrus docmac, Heterotis niloticus* etc. Among the introduced species common carp (*Cyprinus carpio*) and Chinese carps are now available in many African countries. Standard techniques of breeding and cultivation of these species are available, however, only in few places where these techniques are practiced systematically.

5. CONSTRAINTS IN AQUACULTURE RESEARCH IN AFRICA

5.1 Aquaculture Research when carried out on a regional basis can lead to better understanding of the problems as well as development of suitable technologies. Establishment of Regional Centres will help in identifying and tackling problems of local aquaculture interests in relation to wider regional projects. The establishment of the FAO/ UNDP/NIOMR African Regional Aquaculture Centre at Port Harcourt and the planned sub-centres is the first step towards this.

5.2 At present there is a lack of adequately qualified and trained aquaculture scientists to carry out research and over a period sufficient numbers of scientific personnel have to be built up.

5.3. Infrastructure in the form of laboratories and farms have to be established along modern lines so that research programmes could be implemented.

5.4 There should be collaboration with agriculture and livestock departments so that expertise and resources in many fields could be shared to maximum advantage.

5.5 National and international aquaculture institutions should accept collaboration with established and specialised institutions and universities in Africa and abroad, initially or till newly established centres are well grounded.

6. AQUACULTURE RESEARCH AND TRAINING AT FAO/ UNDP/NIOMR AFRICAN REGIONAL AQUACULTURE CENTRE, PORT HARCOURT, NIGERIA

The Research work conducted so far falls within the broad outline given by ADCP (1980) under outline Research Programme for the African Regional Aquaculture Centre. Brackishwater aquaculture research was carried out at the 3.6ha fish farm at Buguma; since the construction of the freshwatger fish farm and infrastructure at Aluu was not completed, limited work on freshwater species was conducted at the freshwater fish farm at Okigwe, Imo State.

6.1 Brackishwater fish culture

Among the various species of Cichlids occurring in the West Coast of Africa *Sarotherodon melanotheron* and *Tilapia guineensis* are the common species occurring in Buguma fish farm. Hence from the beginning research was directed towards development of suitable technologies for culture of both species. While the former is a paternal mouth brooder the latter is a substrate spawner. *S. melanotheron*, though considered a plankton feeder, is known to consume algae, detritus, sand and invertebrates when cultivated in ponds. Similarly *T. guineensis*, though known as a macrovegetation feeder, is also known to consume algae, detritus and other invertebrates whilst under cultivation.

Fish culture work carried out with both species when stocked at density of 2 fish/m^2, with supplementary feeding as well as with fertilisers, gave a production of 2.5 - 3.0 tons/ha/yr. However, this included a high percentage of smaller-sized fish. While standard methods of pond preparation, fertilisation and pond management were adopted, fish were fed with poultry feed with a protein content of about 20%. The rearing period lasted 3 - 4 months. At the time of harvest there was a 400 - 600% in fish numbers but the so called market sized tilapia (50g) constituting only about 25%. The different feeding systems adopted indicated that there has been no significant difference in growth response of fish fed with NIOMR fish pellet (35 percent crude protein), a wheat bran mash (15 per cent crude protein), a poultry layer mash (15 - 19 per cent crude protein) or with fish receiving a supplementary feed but pond receiving only fertilisation. This possibly could have been due to the relatively low standing crop of fish (starting av. 198kg/ha and end of culture period av. 1,171kg/ha). The cost of one kg fish produced ranged from Naira 0.067 to 1.86.

6.2 Culture of Chrysichthys nigrodigitatus

The species enjoys excellent market in Nigeria as well as in some other West African countries and because of its fast growth rate the species is being cultivated in Ivory Coast, Nigeria and a few other countries. Hence research work has been initiated at Buguma and Aluu. Under supplementary feeding the growth of the stock is being monitored and plans are underway for hypophysation of the species leading to seed production.

6.3 Acclimatisation of 0. niloticus to brackishwater conditions

Preliminary trials indicated the species could tolerate salinity up to 25ppt, beyond which mortality occurred. The experiment is in progress and needs further confirmation.

6.4 Hypophysation of Clarias lazera and large-scale seed production

In the absence of facilities at Aluu and at the request of the Officers of the Federal Departments of Fisheries, Okigwe, Imo State, the technique of hypophysation of *C. lazera* was demonstrated at 4 fish farms. The fishes were bred with carp hypophysis and the technique of using synthetic Kakabans was demonstrated.

6.5 Mono-sex culture of S. melanotheron and T. Guineensis

When the fishes attained a size of 30 - 40g they were manually sexed by examining the genital openings as well as the relative size differences of pelvic fins. This has given an accuracy of over 70% males. However, the method is time consuming.

6.6 Other aspects

Several important and related research aspects in connection with brackish and fresh water aquaculture were carried out by the aquaculture trainees as part of their curriculum, under the guidance of ARAC staff. These included: Studies on the food and feeding habits, maturation and fecundity, physiological studies including salinity tolerance, influence of various physico-chemical parameters on the growth, survival and production, use of various anaesthetics in fish transportation and control of the predators and pests in the pond. These items of work were carried out mostly on *S. melanotheron, T. guineensis, T. zillii, O. niloticus, Clarias lazera, Hemichromis fasciatus*, a few predators and oysters.

7. TRAINING

The one year training course for senior aquaculturists (post-graduate level) started in 1980 at ARAC, continues with an increasing number of participants. Four courses have been completed bringing the total number of graduates to 82; the fifth course (1985) is on-going with 24 trainees. The countries that have participated are Ethiopia, The Gambia, Ghana, Kenya, Liberia, Malawi, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, Cameroon, Central African Republic, Congo, Gabon, Guinea, Ivory Coast, Mali, Rwanda, Senegal and Zaire. The successful candidates are awarded a Diploma by ARAC and qualifying candidates an M. Tech. by Rivers State University of Science and Technology. The course is conducted in English and French. The funding agencies for the trainees so far include ADB, FAO/UNDP Field Projects, CFTC, USAID, GFID, EEC and some governments. Estimated expenditure for an individual trainee per year is about US$9,500.00.

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DEVELOPMENT OF INDIGENOUS SPECIES

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1. DEVELOPMENT OF INDIGENOUS SPECIES

When we endeavour to bring a species into culture we are taking the first steps on the road to domestication. Domestication can be defined as the condition wherein the breeding care and feeding of an animal are more or less controlled by man. When we look at aquatic organisms it can be seen that very few of the enormous number cultured world wide would fall into this class. This is because of the relatively recent emergence of aquaculture world wide. There are only a few 'established' domesticated species and these include the European and Chinese carps (*Cyprinus carpio*), the ornamental carps (*Carassius auratus*), and the Rainbow trout (*Salmo gairdneri*). These fish have now been cultured for long enough for different strains to have arisen. The majority of the other species in culture can still be regarded as being essentially 'wild' in their genetic makeup. This has the disadvantage in that the characteristics of these species are not truly understood, but hopefully they still contain the enormous amount of genetic variation or potential for improvement exhibited in natural populations. Domesticated land animals have undergone centuries of genetic improvement either applied consciously or subsconsciously and in some cases developed over hundreds of years into forms hardly recognisable from their natural progenitors. Today with the improved understanding of the underlying genetic mechanisms it should be possible to accelerate the general improvement and by simple manipulations obtain rapid improvements in particular areas. Genetic improvement cannot proceed on its own; it must go hand in hand with improvements in husbandry practice. The further genetically developed strains depart from the natural forms, the more closely the artificial culture environment needs to be controlled so that natural selection does not operate against the proposed improvement. This is because genetic improvement often strips away the natural defence mechanisms which allow a species to survive in the wild, thereby allowing more energy to be concentrated in improved traits.

2. BIOLOGICAL DESCRIPTION

When an organism is found to have potential for aquaculture one of the first objectives should be a total biological survey of the species, and should try to cover the organism's complete life cycle. Much information will probably be available in the statistical records of the fishery and from local knowledge of the fishes' population structure. Important information such as the organism's environmental tolerances and optimal habitat can be gained from the fishes' natural habitat preferences. Analysis of commercial catches can give evidence of food preferences (gut contents) throughout the year and examination of gonads can also determine the age of maturity of the different sexes and appropriate time of natural spawning. Spawning behaviours and information on the type of eggs and mode of development of the young organisms is essential for successful development of artificial spawning.

In many cases with some more established culture species, much of the organism's biology has remained unknown and geneticists are having to go back to wild populations to study many of the above factors before genetic improvements can be undertaken.

Once a biological profile has been obtained it should be much easier to establish a suitable culture regime from the outset. The initial introduction into culture is often made using wild caught fingerlings, juveniles or adults. It will be the job of aquaculturists to optimise culture conditions. This will require some form of experimental design which will allow the use of different stocking densities, feeding regimes, or other parameters which may affect the organism's production. Often a good measure of the success of a husbandry practice is a direct comparison with the natural observed growth rate.

Spawning of the new species is usually the first major difficulty encountered in the development of a new species. Many tropical and marine species have not progressed past the wild capture stage because of this very problem. Spawning in many fish often requires a number of triggers to initiate maturation and eventual ovulation. These are often not present in the new culture environment. Known triggers include day length, increased/decreased temperatures, salinity, changes in water level, turbidity and floating debris. It may be possible to devise methods for reproducing one of these or the correct sequence of a number of these in hatchery practices. Often gonad maturation can be obtained but the final ovulation is not possible because of the lack of the required stimuli (flowing water, mating behaviour). This can often be overcome by inducing spawning with injections of pituitaries from mature fish species such as carp.

After successful spawning, larval survival often becomes the major constraint. In general the smaller the egg the more difficult it is to successfully rear the organism, because of the requirements for the correct sized food organism. The techniques involved in rearing fry from many marine species usually require expensive hatchery and live food rearing facilities. However, as the number of successfully reared species increases so the technology will become more available. A major breakthrough is likely to involve the use of suitable artificial diets in a micro encapsulated or micro bound state which can be made to suit the particular nutritional requirements of each species and so greatly reduce the expense and complexity of existing fry rearing hatcheries.

Serious genetic improvement cannot really occur until the organism has been successfully reared completely through its full life cycle and routine husbandry practices developed. At this stage it should be possible for the aquaculturist to state the problems exhibited by the species and give explicit objectives for improvements in the culture performance under existing conditions.

Two quite different approaches may be made towards genetic improvement. First is the conventional approach of selection, in which traits are progressively altered through the generations. The second is more direct, and involves the use of manipulation which often immediately generates the desired response. It is because the latter category offers an immediate improvement at the lowest cost in terms of effort that I will deal with these first. They include strain evaluation, hybridization, cross breeding, sex control, polyploid production, special breeding and genetic engineering.

3. STRAIN EVALUATION

As I have already mentioned, very few fish species have been cultured for long enough for individual strains to be recognised. The exceptions are the rainbow trout and carp. When different strains of either of these species are compared under standardised conditions often quite clear differences in performance are observed. In this case the strain with the characteristics closest to your local requirements can be chosen. Natural populations of many organisms are often split into many sub-populations inside the species range. When the different characteristics of individuals from these populations are compared under the same conditions, large differences in performances and other commercially important attributes can often be observed. This type of comparative performance study will allow the choice of strains with much higher threshold values for a given trait. It may take many years of genetic selection on a randomly chosen strain to reach the threshold value of an existing natural population.

4. INTERSPECIFIC HYBRIDIZATION

Fish and many other aquatic animals hybridize readily and large numbers of different hybrids have been reported. There have been many attempts to produce superior fish for aquaculture and in many cases these have been a failure. In general, interspecific hybrids are intermediate in performance between the parental species. However, the recombination of important traits from the 2 parents into a single individual often gives the hybrid a commercial advantage over either parent in the culture situation. Examples of such successes are: The hybrid between the Beluga (great Russian sturgeon) *Huso huso* and the diminutive starlet (*Acipenser stellatus.*) The hybrid is intermediate in growth, but can tolerate a freshwater environment and so avoid esturinal pollution; a major problem for the andromonous Beluga.

The hybrid between *O. niloticus* × *O. aureus* not only gives a skewed sex ratio (80% male) but gives a fish which is intermediate in growth but has increased cold and saline tolerance, important for the marginal culture conditions in Israel.

5. CROSS BREEDING

This is different to hybridisation in that it involves breeding from unrelated animals or plants from the same species. It is normally practised on inbred lines; 2 inbred lines being crossed to produce an F1 hybrid, individuals of which are usually highly uniform because they inherit uniform genes from each parent. The F1 hybrid also shows improved performance over its parents. In fish, the crosses between domesticated strains or geographic races have almost always shown the crossbreed to be intermediate in performance to the parents.

At present no deliberate inbreeding has been attempted on fish species to produce uniform inbred lines. However, unintentional inbreeding caused by low numbers of broodstock and poor hatchery management is the main threat to many existing hatchery populations. The rate of inbreeding (close relatives mating) often causes loss of viability and performance greater than the rate at which genetic improvement can improve a stock. Inbreeding can cause increased mortality, increased food conversion ratios, increased deformities, decrease in disease resistance and reduced fecundity, all of which can seriously degrade the commercial status of hatchery populations.

6. SEX CONTROL

Sex control is often the most successful way of improving the performance of many cultured species, because both sexes are not always equally useful, or because of problems with excessive reproduction.

In tilapia the male is the fastest growing sex and monosex populations also overcome the major problem of overpopulation of ponds by reproduction. In many species the female is the preferred sex, particularly in salmonids.

Fish show nearly every possible sex determination mechanism known from environmentally determined sex through hermaphrodism multigenetic systems, to sex chromosomes. It is still not known which genes are involved in sex-determination, but it is often possible to manipulate the sex of the fish by the administration of hormones at the appropriate time during development. This technique may be used directly to produce monosex populations directly as in 'tilapia' or to produce monosex lines by breeding sex reversed individuals.

7. POLYPLOIDY

Polyploids are organisms with more than the usual set of chromosomes. Triploids have 3 sets and tetraploids 4, (higher levels are rarely encountered in animals). The method of producing such polyploids involves interfering with the normal maturation of the female chromosome set of the egg. Triploids are formed by the suppression of the second meiotic division in females and tetrapolids by the first meiotic division of the fertilised egg. (see diagram).

The use of polyploids was first proposed for the possible farming of marine flatfish, since in such fish the development of gonads can be a serious waste of energy in a culture regime. The onset of maturation in many fish is also accompanied by a decrease in growth rate and often serious loss of condition. The theory behind the production of triploid fish is that they are theoretically sterile. In general the females are usually, however males still produce testes but the sperm are usually inviable. Triploids have been produced in a number of different species and the use of all female triploid rainbow trout has revolutionised the rainbow trout industry in the U.K.

The technique for inducing tetraploidy is similar to that for triploidy (see diagram). In theory, tetraploids can be produced by timing the shock to coincide with the first mitotic division of the egg. So far, results of experiments have been inconclusive. Theoretically if tetraploids could be produced and grown to maturity they would be of great importance in the production of triploids by crossing tetraploids with normal diploid individuals.

8. SPECIAL BREEDING (Gynogenesis)

Gynogenesis is the activation of an egg by a genetically inert spermatozoan and the resultant haploid constitution can be made diploid by the

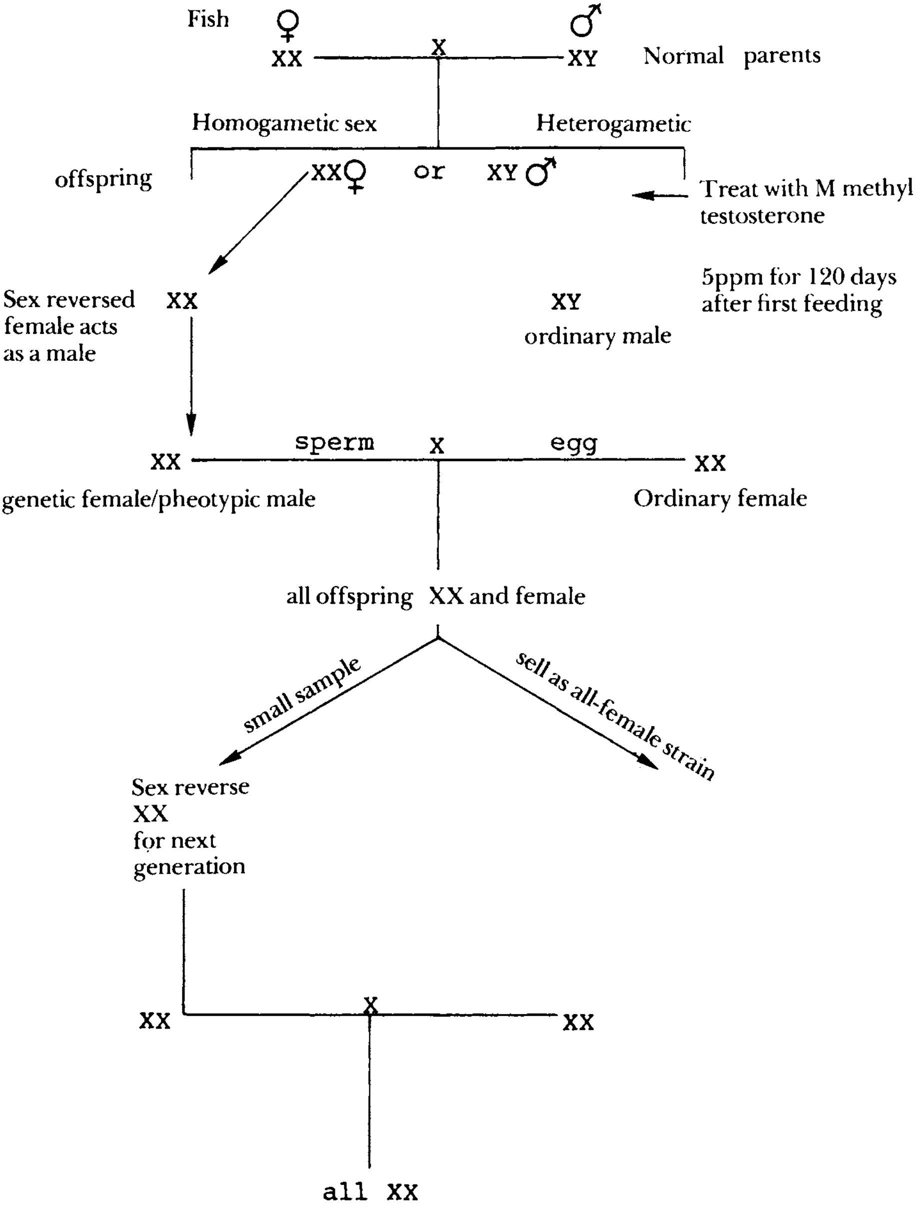

Diagram of the procedure for the production of all-female lines of rainbow trout.

application of shock treatment as in induced polyploidy. The advantage of this technique is that it is a rapid method of producing isogenic lines, one generation of gynogenesis being equivalent to 8 or more generations of full sib mating. This technique gives geneticists a rapid means of fixing strains with particular culture characteristics, and has important implications for studying the genetic mechanisms underlying traits such as sex determination in fishes.

9. GENETIC ENGINEERING

This is a new and potentially important area for the genetic improvement of aquatic organisms. The essence of the technique is the identification of individual genes controlling some important trait. These genes can be isolated from one organism and can be inserted into another, thereby conferring the ability to produce the new material. Several genes have been isolated and have been successfully transferred to bacteria for the production of materials such as insulin. Genes have been transferred into higher organisms such as mice but the problems is to get the genes to operate in a regulated fashion within the cell.

10. SELECTION

This is the classical view of what genetic improvement entails. The evidence is that possibly every characteristic of fish can be modified by selection, but the question is how much effort will be required and what will be the possible benefits? Genetic selection requires that there is a clear objective, usually growth rate. Growth rate has long been an obsession with fish farmers. Despite this interest, little real progress has been made in selection programmes. Growth in fishes is very plastic and the level of additive genetic variation is often quite low.

Reports given in the literature show improvements of between 0 - 33% per generation but on average 3-5% improvement/generation. It can be seen that with such a low response, particularly in long generation time, organism improvement is likely to be a long term aim. It is also important to run control experiments to determine the magnitude of improvement over and above an unselected population as this should help to separate out improvements caused by husbandry effects.

The majority of the techniques outlined in this paper are dealt with in a variety of published papers and books. Useful reference sources are:-

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FISH FEED TECHNOLOGY

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1. INTRODUCTION

The role of 'Fish Feed Technologist' in aquaculture development should be defined at the outset. *The fish feed technologist is concerned with the study of the food and feeding of farmed fish.* This includes the food and feeding of fish under extensive, semi-intensive and intensive culture conditions. All too often it is believed that fish feed technology deals only with the feeding of fish within intensive culture systems, with its consequent use of 'complete' pelleted rations and associated manufacturing equipment. However, the crucial role played by natural pond organisms in the nutrition of fish within 'village level' or semi-intensive systems contrasts markedly from the intensive culture system where natural food organisms play little or no role in the nutrition of fish. Clearly, each particular culture system must be considered as being unique and evaluated on its own merits. In fact one of the major stumbling-blocks in the past to the development of a feeding technology for use at the rural or 'village level' has been due to the direct application of technologies used within intensive culture systems (for which most information and expertise exists). This paper will endeavour to highlight the research needs for the development of an appropriate 'village level' feeding technology.

2. FEEDING OPTIONS AVAILABLE TO THE BASIC VILLAGE LEVEL FARMING UNIT

In this discussion paper the basic village level fish farming unit is regarded as consisting of a single 100 m^2 earthen pond owned or operated by one or more family units. The aim of the farming system being to produce fish for home consumption using locally available resources at a minimum cost, with the possible benefit of an additional cash income from fish sales. It is anticipated that no cash funds would be available to the farmer or family unit for the purchase of fry, fertilizers, feeds or farm equipment other than that obtained through normal wage earnings.

The food and feeding of fish cultivated within such a system can be viewed at four different levels of refinement or input:

2.1 No fertilizer or feed inputs - basic rearing system where fish growth is totally dependent on the natural food population within the pond ecosystem. Fish growth will therefore vary depending on the natural productivity of the water body and fish stocking density. Fish stocking densities of $< 1/m^2$ are generally used with this rearing system.

2.2 Fertilizer input only - inorganic and/or organic fertilizers are applied to the pond so as to enhance the natural production of fish food organisms and so increase the fish production capacity of the pond. Organic fertilizer is used here in the context as resulting from livestock production and consisting of untreated (other than drying) animal faecal matter which is not generally directly consumed by fish. In view of the higher cost and limited availability of inorganic fertilizers in Africa, it would appear to be more advantageous to use organic fertilization regimes (possibly through fish/animal integration farming techniques) within 'village level' fish ponds. Recently, anaerobic and/or aerobic composted agricultural by-products have been employed as organic pond fertilizers with some success (M.J. Vincke, personal communication 1985).

2.3 Fertilization and supplementary feed input - this feeding strategy is typical of a semi-intensive rearing system. Here, in addition to the use of fertilizers for the production of natural fish food organism within the pond, low grade/value agricultural and animal by-products are used directly as an external supplementary fish feed. Supplementary feeds are defined here as low value agricultural and animal by-products (including faecal/agricultural composted materials) which can be directly consumed by fish. However, when used in excess these products may also exert a fertilization effect on the water body. With this feeding strategy, higher fish stocking densities are possible ($2/m^2$) and consequently fish yield/unit area.

2.4 Formulated 'complete' diet as the sole feed input - this feeding method is typical of an intensive culture system. In contrast to the above feeding strategies fish growth is totally dependent on the external provision of a manufactured high quality diet containing a predetermined nutrient profile or the use of a single food item of high nutrient value (i.e. trash fish). In view of the much higher stocking densities employed with this feeding strategy little or no nutritional benefit is gained by the fish from natural food organisms within the pond (the amount of natural food being available/fish at high stocking densities being very low). Although considerably higher fish yields can be achieved with complete diet feeding the capital and operating costs of fry and feedstuff procurement and feed manufacture are generally well above the financial ceiling of the individual village farmer. However, the main constraint to this feeding strategy appears to be the availability of suitable feed ingredients of sufficient quality and quantity within the village community.

The ultimate choice of the feeding strategy to be used will depend to a large extent upon the feeding habit of the fish species chosen (herbivore, omnivore, carnivore), the local availability of fertilizers and feeds, the market value of the fish species farmed, and on the financial status of the farmer. However, of the four feeding strategies mentioned it is generally believed that the most appropriate at the village level is one that uses a combination of pond fertilization (preferably by integration with livestock) and supplementary feeding. This semi-intensive feeding method has the necessary flexibility in that fish growth is not dependent on a single food source but on a combination of different feed types. It is essential that the feeding strategy chosen has this flexibility as fertilizer and feed inputs may vary over a growing season depending on availability and the financial status of the farmer. From a nutritional viewpoint supplementary feeds generally provide the fish with an energy source for growth, whereas the natural pond organisms provide the essential nutrients for the maintenance of the growth processes. Supplemental feeding also offers other advantages to the farmer:

2.4.1 Facilitates the use of agricultural and animal by-products which are currently not being utilized by the community as a feed source for human and/or livestock consumption, with consequent improvement in land productivity.

2.4.2 Facilitates faster fish growth.

2.4.3 Permits the use of higher fish stocking densities.

2.4.4 Higher fish yields and crops are possible over the growing season.

It should be emphasized however that the benefits of supplemental feeding will depend upon the agricultural/animal by-products used, the fish or fish species cultured, fish stocking density, and the natural productivity of the water body. In addition, each pond ecosystem must be considered as being unique (depending on climate, location, soil type, water quality and fertilizer input) and so it should be remembered that the success of a particular supplementary feeding regime in one location need not necessarily apply to another. This is in sharp contrast to the intensive culture system where strict controls are normally placed on water quality and feed inputs.

RESEARCH NEEDS FOR THE DEVELOPMENT OF A 'VILLAGE LEVEL' FEEDING STRATEGY IN AFRICA

Particular emphasis will be placed in this discussion paper on the identification of research needs for the development of a supplementary feeding based farming strategy.

3. IDENTIFICATION AND SELECTION OF FEED INGREDIENTS SUITABLE FOR FISH FEEDING

In view of shortage of feedstuffs in Africa for human and conventional livestock consumption, emphasis must be placed on identifying and utilizing hitherto unused agricultural and animal by-products within the community. For the 'village farming unit' ingredient selection must therefore be based on low quality and value products, and fish species selected which feed low on the aquatic food chain. By utilizing agricultural and animal by-products which are not currently used for human and livestock feeding the village fish farmer would be seen to be an asset to the community rather than a competitor with the traditional agricultural or livestock farmer.

A survey should be conducted for each potential community so as to identify hitherto unutilized or unutilizable resources. Products which may be considered in this category include:

kitchen waste
brewery waste
'spoiled' animal feeds
plant leaves/tubers/roots/ seeds
maize cobs
mill sweepings,
abattoir waste (animal offal, blood, rumen contents)
aquatic macrophytes
composted agricultural/livestock manure
fruit – spoiled peelings
oilseed hulls/residues

Final selection of potential feed ingredients should be based on the following criteria: in order of importance, these include a) cost (if at all); b) availability (both in quantity and time; it should be possible to use different 'categories' according to the seasonality of products); c) handling or processing requirement prior to feeding; and d) nutritive value (composition). In the case of feed processing and handling particular emphasis must be placed on using locally available materials and customs (i.e. grinding techniques, composting, drying, mixing, storage, cooking).

4. FEED FORMULATION

In contrast to 'complete' diet feeding, where rations are formulated to a pre-set nutrient level for each fish age class, the formulation of a supplementary diet is dependent on the standing crop of fish within the pond and the consequent availability of natural food organisms. For example the studies of Hepher (1979) have shown that 'for conditions at the Fish and Aquaculture Research Station at Dor, Israel, there was no difference in carp growth rate in ponds when fed cereal grains (sorghum), a protein rich pellet containing 22.5% protein up to a standing crop of 800 kg carp/ha. There was no difference between the effects of pellets containing 22.5% protein or pellets containing 27.5% protein up to a standing crop of 1400 kg carp/ha.' Similarly, no beneficial effect of dietary vitamin or mineral supplementation was observed with tilapia or carp either in ponds or cages (within the pond) at stocking densities of $2/m^2$ and $100/m^3$ respectively (ca. 400 g fish; S. Viola personal communication, Ashrat, Israel, 1985). Although it should be remembered that these results apply to the local conditions of soil, climate and pond productivity in Israel, the results of these feeding trials will also apply to the African village level fish farm.

From the above discussion it follows that dietary energy is the first limiting factor at low fish stocking density (when natural food availability/fish is high), whereas at high stocking density dietary protein and other essential nutrients also become limiting and therefore have to be supplemented. From a farming viewpoint it can be seen that the protein and nutrient content of the diet will have to be increased with increasing fish growth (standing crop) and diminishing natural food availability. To date, little work has been conducted in this subject area in Africa.

At its basic level supplemental feeding merely involves the feeding of a single food item throughout the culture period. Such a feeding strategy is typical of a 'village level' fish pond where fish stocking densities are normally low and available feed resources poor. Clearly much work needs to be undertaken on the development of supplementary fish feeds for use at higher fish stocking densities. However, caution should be given to the extrapolation of results obtained from large ponds to smaller ponds (and vice-versa) in view of the possible surface area effect on natural food productivity.

5. FEED PRESENTATION

The success of a particular supplementary feeding regime will depend to a large extent upon the physical form of the diet fed (dry/wet mash or pellet) and the cost of the finished feed. At its simplest level feed presentation merely involves administering the feed in its fresh or ground state to the pond. This feeding strategy is most suited to ponds having a low stocking density (or standing crop) and high natural productivity. However, at high stocking densities there is no doubt that pelleted feeds (dry or moist) are more beneficial and economic in terms of feed conversion efficiency (wet fish gain/unit of dry feed input) and fish growth. At low stocking densities however the beneficial effect of pelleting may not be so great. For example, in the Central African Republic no difference was observed in the growth response of pond reared *Tilapia nilotica* fed a 30% protein supplementary diet either in ground or pelleted form (miller, 1979). During this 62-day feeding trial low stocking densities were employed (2/m^2; initial and final fish standing crop of 480 and 1200 kg/ha., respectively) and fish fed at 4% of their estimated body weight once daily (9.00 a.m.). In view of the exceedingly high cost of the pelleting prices reported, feed input cost/kg fish gain using the pelleted feed was found to be almost double that of the ground meal.

Under these circumstances the additional costs of pelleting were not compensated by an equivalent increase in fish production. Clearly special attention must be paid to the physical form of the supplementary diet used and the economic cost of processing.

6. FEEDING LEVEL AND FREQUENCY

In contrast to 'complete' diet feeding, no accurate feeding tables exist for the feeding of individual supplementary fish feeds which take into account fish species, age, class, stocking density and natural food availability (for use under African conditions). This situation must be remedied if maximum benefit is to be gained from supplementary feeding. For example, at the species level, it has been suggested that the supplementary feeding rate for tilapias should be lower than that for common carp (Cyprinus carpio) (Hepher and Pruginin, 1982). Similarly, the poor fish performance observed by Miller (1979) when feeding a pelleted ration may have resulted from the feeding regime employed (fish fed once daily) and the poor water stability of the pelleted ration used (disintegration after 5 min. water immersion). Clearly, optimal feeding rates and frequency of feed presentation must be determined.

7. ECONOMICS OF THE FEEDING STRATEGY EMPLOYED

For the basic 'village level' fish farm to run profitably it is essential that the correct feeding strategy is employed. Simple economic analyses should be undertaken to ascertain the profitability of individual feeding regimes. For example, Table 1 shows hypothetical analysis of two identical fish farming units, one receiving manure as the sole feed input and the other receiving pelleted feed as the sole feed input.

Table 1: Profitability of two feeding systems in a pond environment using identical fish stocking and management techniques.*

	Major feed input	
	Pelleted feed	Manure
Total fish yield (kg/ha/day)	10	5
Total manure or feed input (kg, dry wt./ha/day)	20	25
Food (input) conversion efficiency	2	2
Unit cost of manure or feed ($/kg)	1	0.1
Input cost/kg fish produced ($)	2	0.5
Total input cost/ha/day ($)	20	2.5
Profit/ha/day (where "y" is price/kg fish)	10 y − 20	5 y − 25
If price of fish (y) is $1.0/kg, then profit/ha/day will be	−$10	+$2.5
If price of fish (y) is $4.0/kg, then profit/ha/day will be	+$20	+$17.5
For equal profits to be attained from feeding and manuring, then	10 y − 20 = 5y − 2.5 Solution 7 = $3.5	
Under the above hypothetical conditions when the price of fish is higher than $3.5/kg, it is more profitable to grow them on pelleted feeds, when it is lower it is more profitable to grow them on manure.		

**Example solution based after Wolfarth and Schroeder (1979)*

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TILAPIA HATCHERY SYSTEMS

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1. INTRODUCTION

It is ironic that possibly the major constraint hindering the rapid development of tilapia culture is the shortage of high quality seed for restocking. Yet one of the major problems encountered in pond culture is the excessive reproduction encountered in production or fattening ponds. In recent years the major advances in tilapia production have occurred where the fry and fingerling production have been separated from the ongrowing and fattening stages. This has allowed the use of a number of improved techniques to be developed. This has resulted in several orders of magnitude improvements in the numbers of fry being produced per female or per m^2 of hatchery. This article outlines the main types of hatchery systems used world wide and methods available for the production of higher quality and monosex fry populations for restocking.

2. EARTHEN PONDS

Fry production in earthen ponds is still probably the most widely used system for 'tilapia' fry production world wide. Variation in the production of fry from this type of system is highly variable and strongly dependent on the management practices. The poorest production is found in undrainable or undrained ponds in which there is no routine cropping system.

Successful pond hatchery units utilise completely drainable brood ponds, to facilitate pond maintenance and fish capture. They also assure high pond productivity and practise either a complete draining and capture, or capture routine at 18 day or monthly intervals (depending on size of fry required). Even the best managed pond hatcheries usually only average 10 fry/m^2/mt for first feeding fry

(Israel) or between 4-8 fingerlings/m^2/mt for 3-4 cm fingerlings (Coche 1982, Rothbard et al 1983). This usually means that pond based hatcheries need to be extensive to produce large numbers of seed.

The increased demand for high quality fish fingerling has promoted research into more effective tilapia fry production systems.

2.1 Hapas (net enclosures)

This form of fry production is now extensively practised in the Far East and particularly the Philippines. The system involves the use of fine nylon mesh enclosures or hapas (mosquito netting). These hapas are suspended above the lake or pond bottom on bamboo frames. The broodstock are kept inside the cages where they breed continuously. The fry produced are collected at regular intervals and are transferred to other cages or ponds for ongrowing. A variety of designs and sizes can be used. Any manageable size can be used, the net being suspended from a bamboo frame so the base is about 1m above the lake bottom. The frame is usually fitted with some form of catwalk to facilitate husbandry. Harvesting is simply carried out by crowding the fish into a corner of the net and separating the broodfish from fry, and netting all the fry or only those of a given size.

A double net enclosure in which the broodfish are restricted to a smaller large-mesh net inside the larger fine-mesh net almost doubles the efficiency of the system as the young fish can avoid being eaten. This also facilitates fry collection as the broodfish are easily handled.

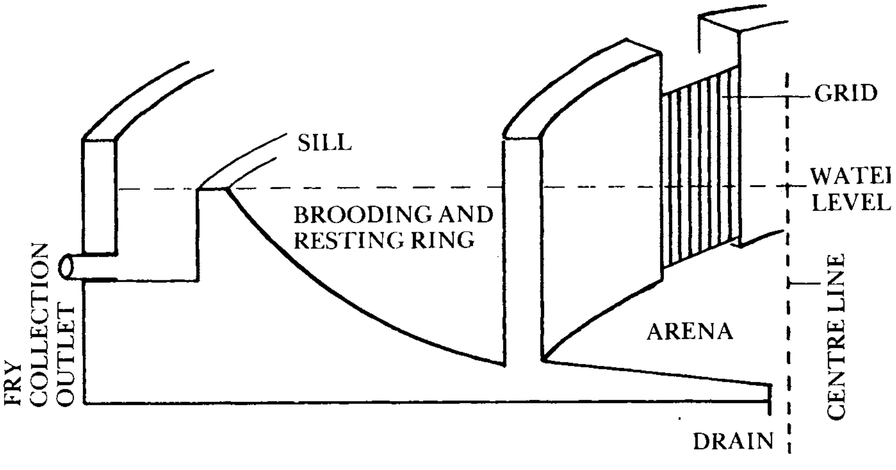
The broodfish will require some form of feeding in this system, so the nets are usually placed in highly productive lakes or ponds and some form of supplementary feeding supplied (rice bran, chicken feed, etc.)

Reported yields for fry from these systems are between 200 fry/m^2/mt (Guerrero and Garcia, 1982) and 880 fry/m^2/mt (Coche, 1982). The stocking density and sex ratio of the broodfish can play a major part in fry production and appears to be optional at 4-5 fish/m (100gm) and a sex ratio 1 ♂ : 3 ♀. Further intensification often results in an overall decrease in fry numbers. The hapa system of fry production is probably the easiest way of improving seed availability in a variety of culture environments such as reservoirs, lakes, large ponds and small village ponds. It offers a system which is manageable by one man, and would allow fry production to be separated from ongrowing in even a single pond. It is also adaptable to small-scale, owner-operated enterprises which would require a minimal outlay and could be easily expanded as demand increases.

3. TANKS

A number of tank systems have been developed in recent years to improve fry production in several countries. These range from plastic swimming pools (2m - 6m dia., 60cm deep), through concrete, fibreglass, asbestos, and steel tanks. These need to be fitted with a simple inflow and outflow device. The broodfish are stocked and either the total seed is collected at regular intervals (14-18 days) or fry are netted as they appear. The most efficient method is the collection of the total seed produced but this necessitates some form of incubation system to maintain eggs or larvae until first feeding. Simple fry collection is almost as efficient and production can be as high as 688 fry/m^2/mt (Snow et al 1983) and 1024 fry/m^2/mt (Coche 1982).

More complex tank designs which utilise the natural behaviour patterns of the broodfish fry to allow a more automated harvesting technique have been developed (Lovshin and A.B. Da Silva; Haller and Parker). Probably the best known of these is the Baobab arena system. This consists of a large circular concrete tank which has been divided into 3 separate rings (See diagram). The central ring is known as the arena and is isolated from the rest of the tank by a wall with



vertical grids which allows free passage to females but restricts the male to the central area. The next ring is designed to give the females an area to come into breeding condition, and is also supplied with 'hides' so that brooding females can remain undisturbed. The females can enter or leave the central arena at will through the grids provided. The bottom of this ring is sloped up to a shallow lip which is covered by a few mm of water and which then drops into the outside fry collection ring. This accommodates the brooding female's natural behaviour of releasing her fry into shallow water. The fry so released hopefully swim over the shallow lip into the outer collecting ring which can be drained on a regular basis, the fry being piped straight into suitable ongrowing ponds. This system has been used for a number of years and on average produces 100 fry/m^2/mt (J. Balarin pers. Com.).

4. TANKS/HAPAS

Probably the highest fry production levels recorded are for combined tank/hapa systems where large tanks are divided into separate net enclosures. This system allows a very accurate stock control since the broodstock are easily managed and can operate at an individual fish level. This method utilises the total seed collection method whereby individual females have their broods released manually and are then transferred into all-female tanks for reconditioning by intensive feeding. Rested females replace them in the hapas. Tagging of spawned females allows the rapid identification of infertile individuals and enables maximum utilisation of hatchery facilities. (2202 fry/m^2/mt, Hughes and Behrends, 1983; 3000 fry/m^2/mt, McAndrew, unpublished trial).

5. IMPROVEMENT OF FRY QUALITY

Once a regular hatchery practice has become established, improving fry quality for restocking becomes much easier. Often the easiest option to improve performance is the selection of a better tilapia species. It is now generally recognised that pure *O. niloticus* is the fastest growing 'tilapia' in freshwater. The switch from *O. mossambicus* to *O. niloticus* has been one of the major reasons for the impressive production levels now seen in countries such as Taiwan and the Philippines. This has been particularly so for the 'Red' tilapia strain of Taiwan which was initially a 'red' *O. mossambicus* strain which was subsequently hybridised with pure *O. niloticus* and in some cases with *O. niloticus* × *O. aureus* hybrids. The new hybrid has the 'red' colour of the *O. mossambicus* but improved growth rates from the *O. niloticus*.

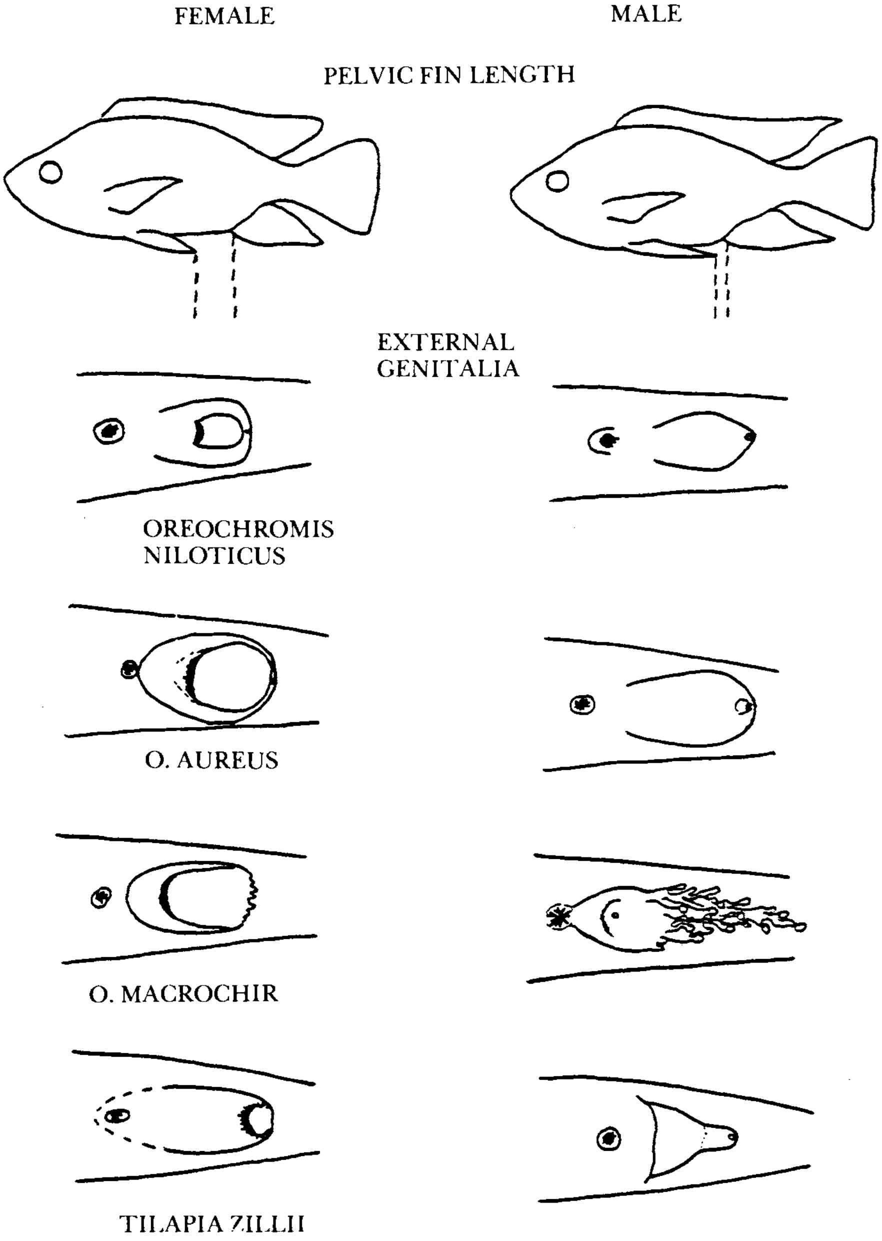
It is however pointless in trying to improve any species unless it can be maintained pure, and not lost by the infiltration of 'wild' species or uncontrolled inbreeding by poor stock management. Improved strains have been introduced into several countries and have lost their original performance particularly after the infiltration of *O. mossambicus* into the strain. The hatchery techniques described in the previous section should greatly reduce the risk of uncontrolled hybridisation, particularly if fish are maintained in some form of tank, and only fry from known pair matings are used for broodstock replacements. The major problems associated with tilapia can all be overcome by good management and husbandry rather than by the use of expensive 'hardware'.

6. MONOSEX FRY PRODUCTION

Hand sexing

This technique makes use of the clear dimorphism between the sexes in 'tilapia' species. Tilapia can be sexed by the differences in the urinogenital opening, fin morphology and adult colouration. Of these, the genitalia morphology is the most reliable and fin morphology can confirm the initial sexing. This process is much easier in large fish as the urinogenital openings are more obvious. However, skilled hatchery workers can achieve over 95% male populations on 5-7cm fish. Simple aids such as magnifying glasses and the use of coloured dyes (alcian blue, ink, malachite green) to accentuate the genitalia can significantly improve the efficiency of recognition. It is essential that hatchery workers are trained in the technique and understand the importance of obtaining all-male populations. Monitoring of the accuracy of the workers can be assessed by 'in house ' testing of production ponds at the hatchery or demonstration farm, or by extension workers counting the sexes in the harvests of farmers supplied by the hatchery.

With this method some form of fry ongrowing system is required to produce advanced fingerlings for hand sexing (approx 20 gms). Fish of this size are also more able to resist handling and stress and will have a better potential for growth particularly in low input, low-management village level ponds. Hand sexing is a relatively inefficient means of producing an all-male population in that almost half of the fish are not suitable for restocking and that they represent an investment in food, ponds, water and labour. The female fish which are not used for replacement broodstock may be sold on the local market if there is a small fish market, or the fish may be used to feed other livestock such as pigs or crocodiles, the waste from which may be used to fertilise the fingerling ponds. The female fish may also be dried and turned into fish meal and be mixed with other



Diagrams to show pelvic fin morphology and genitalial differences in four commercially important tilapia species.

components (rice bran) to make a good quality, supplementary feedstuff for fish or poultry.

Hand sexing can be taken at any stage in a pond production cycle especially where fry production has become excessive. The pond can be drained and netted, and the males can be kept and moved into another pond until they are of a marketable size. Once the trained staff have become proficient, success will be measured in the number of farmers requiring new fingerlings for restocking as they should have little or no fry to carry over into their next production cycle.

7. HORMONE SEX REVERSAL

This offers one of the most cost effective ways of producing 100% male populations for restocking. The system does not require a tank or hapa-based hatchery so that fry can be collected at the yolk sac of first feeding stages, and no later than one week after the fry are released from the female. The fry are treated by feeding a finely divided feed which has been impregnated with a suitable hormone. To guarantee success it is important that the fry are not allowed any natural feeding either by grazing algae or faecal material. This necessitates that the fry must be kept in some form of tank with good cleaning characteristics. The hormone feed can be locally produced from rice bran and fish meal (trash 'tilapia') and is ground into a very fine powder, 250 m. The feed is treated with one of the synthetic androgenic hormones Mα Methyltestosterone. The hormone must first be dissolved in alcohol (95%) and is then sprayed on or mixed with the dry food. The dosage is normally between 40 - 60ppm of hormone in the diet which is the equivalent of:

40 gms - 1 tonne feed
10 gms - 250 kg feed
1 gm - 25 kg feed

for 40ppm or:

60 gms - 1 tonne feed
15 gms - 250 kg feed
1.5 gms - 25 kg feed

for 60ppm feed.

The normal time for feeding this diet is for the first 30-40 days. If the young fish are all newly hatched and can be kept in clear water the lower dose for 30 days may be sufficient, whereas in non-ideal conditions the higher dose for a longer period may be required. If it is assumed that the FCR is 2:1 or even 3:1 then between 125,000 - 83,333 1gm fry could be produced from only 10gms of hormone would be around £10 and the necessary alcohol £5. As mentioned the feed could be made from local products or be dispensed from a central source. The inputs for such a hatchery set up should not be outside the resources of a government hatchery facility particularly if the tanks, brood, and sex reversals are installed with the other infrastructure.

There has been some disquiet about the use of hormones in food for human consumption. It has however been clearly shown in a number of surveys that at the levels used in such sex reversal procedures the hormone is quickly metabolised by the fish and that 99% of the hormone has disappeared within 48 hours of the last feed. It can be seen that as these fish will take up to 6 months before they are ready for marketing, little risk is involved if these procedures are undertaken correctly. Recent studies on hormone-treated fish also show an added advantage in that the hormone induces an anabolic effect in the fish which can enhance the growth rate by up to 10% over untreated siblings.

8. HYBRIDISATION

After Hickling's (1960) discovery that a cross between *O. mossambicus* × *O. hornorum* produced all-male hybrid fry there was great enthusiasm for this approach as the way of controlling excess breeding in ponds. However, presently there are not many countries in which this technique is widely used for monosex fry production. Over 25 different hybrid combinations have been attempted but only 6 of these are capable of consistently producing all-male broods. Little is known about the characteristics of these hybrids other than their sex-ratio. In general, hybrid performance can be predicted from the characteristics of the parental species. It appears from the literature that there is little evidence for hybrid vigour between any interspecific hybrids, but that different hybrids can exhibit a range of growth or other performance traits intermediate to the parental species. This is an important attribute in that different traits can be combined in a hybrid to give some advantage over either parent. e.g. *O. niloticus* × *O. aureus* combines the fast growth of *O. niloticus* with the hardiness of the slower growth *O. aureus*. The hybrid is intermediate in growth but displays the hardiness of *O. aureus*. This cross has also the added advantage of producing on average 80% male broods from mass spawnings (Majumdar & McAndrew 1983).

O. hornorum males are the only species which will consistently produce 100% male broods with different strains of *O. niloticus* and *O.*

mossambicus females, the *O. niloticus* × *O. hornorum* hybrid being much preferred because of its better growth performance. The number of hybrid crosses available for all-male hybrid brood production is very limited and success is heavily dependent on obtaining pure species and in being able to maintain their purity. This requires a relatively sophisticated hatchery and management system to ensure the long-term condition of the stocks. The added costs involved may well outweigh any advantages obtained from hybrids, particularly if this results in a dulling of performance when compared to a good single species such as *O. niloticus.*

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EXTENSION

THE ROLE OF EXTENSION IN VILLAGE AQUACULTURE DEVELOPMENT

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1. INTRODUCTION

Extension, in this context, concerns the actions necessary to promote, propagate and spread the practice of fish farming.

Small-scale rural fish farming or village fish farming is generally of the subsistence level, with the aim of converting locally available household scraps, wastes, manures and agricultural by-products to animal protein (fish), using small financial inputs and almost only family labour alone.

With the exception of a few individuals, farmers in most African countries belong to the low-income category. They do not have cash or savings and their purchasing power is low. These potential fish farmers cannot afford to pay salaries and, even less, pay back for hiring heavy machinery for pond construction. He has only his hands, and those of his family, and a hoe or a spade. Simple techniques, therefore, are required to permit the maximum number of farmers to benefit.

Village level fish farming development should always be adapted to the socio-economic and cultural conditions prevailing in the village. The proposed fish farming system must be adapted to the farmer's capabilities and to his surroundings.

When propagating a new technique, the duration of extension activities is very important. The aim of extension in fish farming is to get the villagers into the habit of raising fish in ponds, just as they are in the habit of growing cassava or maize. The creation of new habits takes a long time.

The key person for the success of extension programmes is the field extension worker. The training of such extension workers is of capital importance and should be carefully planned. A large part of their training programme should consist of practical work to be carried out in a fish farming station.

2. ACQUACULTURE EXTENSION SERVICE

Extension is an informal educational process which aims to teach rural people how to further improve their standard of living by their own efforts, for the benefit of the individual, the family, the community and the nation (Bradfield, 1966).

Fish farming, as an economic and social activity, cannot develop successfully without extension work. An efficient extension service needs qualified extension agents, a unified command structure and the financial resources required for the planned extension activities.

2.1 Staffing

An extension service needs personnel, vehicles, training programmes, a minimum of facilities and financial resources. If there is already an existing fish farming extension service, existing extension personnel will have to be redeployed after their participation in a refresher course.

There are generally three levels of extension personnel: the village extension worker, supervised by the regional extension agent and the extension officer in charge of the programme. This is only an indicative scheme and the organisation of an extension service should be flexible. It will usually be most convenient if the administrative and regional set-up of the extension service fit the framework of the general administrative organisation of the country. In this way, the facilities already in place at existing administrative levels can be used (Benor and Harrison, 1977).

The number of extension agents required for the implementation of an extension programme depends on the total number of villagers living in a given area and the number of families which one village extension worker can reasonably expect to cover.

The number of potential fish farmers to be visited regularly by the village extension worker depends on different factors such as the density of population, the roads system, etc. If the fish farmers are isolated and widely dispersed, the extensionist will, maybe, visit only 3-5 farmers a day. When they are living close together, for instance in one valley, then about 5-10 farmers could be contacted every day. This is particularly true during the first year of extension activities when the village extension worker has many tasks to perform (pegging the ponds and the water supply canal, soil survey, etc.).

The regional extension agent supervises and organises the work of 8-10 field extension workers and reports to the extension officer.

2.2 Training of extensionists

The extensionists should be trained in such a way that they can perform all the tasks required to promote the practice of fish farming at the village level. Their training should be very positively oriented to field work.

Extensionists are generally trained in the country during the first phase of the extension programme, by experienced extension officers.

The duration of the training, depending on the educational level of the trainees, varies between 4 and 6 months. Once trained, it is very important to plan regular refresher courses or in-service training courses for the village extension workers.

2.3 Equipment

Each extension worker should have sufficient mobility to visit the farmers once a week or once a fortnight. The means of transport is generally a bicycle or a motorcycle.

Each village extension worker should be provided with some small field equipment, such as a tape measure, a small seine, handnets, litmus paper, spring balances, notebooks, etc., and audio-visual aids, as required.

2.4 Audio-visual aids

Audio-visual aids are tools for the extension worker to use in order to make teaching more effective. They do not replace personal contacts between the extension worker and the audience (Bradfield, 1966).

The simplest types of 'visuals' are real objects (such as a net), samples and specimens (feed or manure), models (such as a monk), photographs and blackboard.

Two other types of visuals are flannelgraphs and flip-books. Flannelgraphs consist of a nearly vertical surface of a rough textured cloth on which symbols can be placed which are backed by similar cloth, sandpaper or flocking. The backing holds the parts firmly in place on the cloth surface. The main limitation of the use of flannelgraphs is that they can only be used indoors because when a breeze blows it would scatter the parts used for a flannelgraph presentation. Therefore, many extension workers prefer to use flip-books. They are made with paper pages fastened between two rigid covers. The flip-book is opened out by the extension worker so that the covers form a stand. Each page has a picture related to the particular point in the extension worker's talk (Bradfield, 1966).

Posters and wallcharts are also useful since they constantly remind the villagers of the principal points of the fish farming extension programme.

Projected visuals such as colour slides, filmstrips and cinema films are also sometimes utilised but their use is not always possible in the field.

3. PHASES OF EXTENSION WORK

Generally speaking, extension activities are developed in four consecutive phases, starting with actions to make villagers aware of fish farming.

3.1 Making villagers aware of fish culture

This is the phase when the villager learns of the existence of the idea of raising fish in ponds but he knows little about it.

The extensionist has to explain the idea using different teaching methods. He will discuss the idea during a meeting in the village. Not everybody will be interested but the aim of the meeting is to develop interest in fish farming.

Depending upon the cultural level of the peasants, the extensionist can use audio-visual aids such as wallcharts, or flannelgraphs display, flip-books and colour slides. In this way awareness and interest in the new idea of fish farming can be created.

The extensionist can also distribute extension leaflets that are left at the village and farmers will discuss the content among themselves.

Radio programmes concerning fish farming can also help to create awareness and interest by informing the villagers.

3.2 Motivation

Once they are aware of the possibilities of fish farming, some of the villagers develop interest in the idea and seek more information about it, possibly asking the extension worker or discussing the matter with a friend who is already involved in pond culture. The extensionist should now motivate the interested villagers and one way to do so is to organise a demonstration or a visit to one of the existing fish farms. There, on the spot, the farmer can obtain all the required information and finally decide whether or not it is worthwhile to try fish farming, on a small scale, as a kind of trial.

3.3 Active extension

This is the phase where the field extension worker helps the villager to build his pond, teaches him how to stock, and fertilize the pond, and how to feed the fish, etc. The extension worker visits the farmer as often as necessary to give him advice and to carry out demonstrations, such as the preparation of compost, sampling of the fish, etc. The field extension worker should teach the new fish farmer all the skills he should know to become an efficient fish farmer.

3.4 Follow-up support

The training of a new fish farmer takes a long time and follow-up support is needed to help the fish farmer to improve his production. The farmer should not be left alone before he has mastered all the techniques involved in fish farming. If left alone the farmer will not be able to solve his problems, will become discouraged and eventually will abandon the pond because of the lack of support from the extension service.

4. DIFFERENT METHODS OF FISH FARMING EXTENSION WORK

In a number of African countries, village fish farming started in the fifties and numerous fish ponds have been constructed in rural areas. The status of fish farming in Africa at the end of the fifties is shown in Table 1.

For several reasons, the development of rural fish farming in Africa came to a standstill in the early sixties and many farmers abandoned their ponds. These ponds still exist in some countries such as Kenya and Zaire and their rehabilitation is possible. Such abandoned ponds have already been rehabilitated successfully, for example, in the Congo, Gabon and the Central African Republic.

When planning fish farming extension, there are generally three different cases, requiring different approaches. The three different cases include:

(i) ponds exist but have been abandoned;
(ii) no ponds exist, but villagers are interested in starting fish farming;
(iii) no ponds exist and potential sites are available, but the villagers have not so far, shown any interest in fish farming.

Each of these three cases will require different extension methods to build up confidence and to convince the villagers that fish farming is a useful activity.

These three cases, and the extension methods to be used in each case, are described in the following sections.

4.1 First case: Ponds exist but have been abandoned

In many countries, rehabilitation of existing, but abandoned fish ponds, will be the first task of a fish farming extension service.

These ponds will have probably been built during the fifties and it requires understanding of reasons for subsequent abandonment and also justifications for rehabilitation of these ponds.

The reasons why village level fish farming came to a standstill are generally the following:

(i) the species used in the fifties were not fast growing and with *Tilapia macrochii*, *T. zillii* and *T. rendalli* the yields were only between 800 and 1,000 kg/ha/year;

Table 1 Status of rural fish farming in Africa (1958–60)
(according to Meschkat, 1967, completed by Vincke, 1985)

Country	*Year of starting*	*Number of ponds constructed*	*Surface area (ha)*	*Production (t)*
Burkina Faso	1956	82	4	2
Burundi	1950	352	65	26
Cameroon	1952	9,000	123	61
Central Africa	1952	11,700	117	117
Congo	1953	12,176	125	125
Gabon	1956	2,000	40	16
Ghana	1953	30	3	3
Ivory Coast	1956	340	8	8
Kenya	1957	12,200	610	192
Liberia	1959	55	17	7
Madagascar	1950	70,000	1,400	840
Mozambique	1956	250	10.5	9
Nigeria	1951	–	61	36
Rwanda	1950	448	84	34
Tanzania	1949	8,000	80	64
Togo	1954	53	8.5	9
Uganda	1958	11,000	410	670
Zaire	1947	122,067	4,058	1,406
Zambia	1961	1,231	100	89
Total		260,984	7,324 ha	3,714

(ii) without adequate fertilisation of the ponds and without regular supplemental feeding of the fish grown in waters with poor natural production, the yields were low and the farmers became discouraged;

(iii) the rearing techniques were not adapted due to the lack of basic scientific background required to obtain high productivity;

(iv) the fish ponds were poorly constructed;

(v) the lack of well trained extension personnel able to train and to teach the farmers.

The extensionist should explain to the farmers that there are now new species and new, more profitable techniques. He should visit the abandoned ponds with the farmers and make sure that they can be rehabilitated. Pursuing the discussions, he should invite the owners of the abandoned ponds to visit the nearest fish farming centre where they could assist in harvesting a pond. During this visit the villagers will obtain all the information concerning the rearing techniques and the yields obtained which will have some effect on him. Some of them will be convinced and will eventually rehabilitate their old ponds and start fish farming again.

In this case, it is very important that the field extension worker visit these farmers regularly to give them correct advice at the most suitable time.

The construction of a demonstration pond near the village is also a good means of convincing farmers, especially if the demonstration pond is one of the abandoned ponds, rehabilitated at the expense of the extension service, in agreement of course with the owner.

4.2 Second case: No ponds exist, but villagers are interested in starting fish farming

This case requires the understanding of why the villagers want to raise fish in ponds. Generally they learn about the possibilities of fish farming through friends or inhabitants of other villages already involved in fish farming.

These villages are already motivated and the extensionist should, as soon as possible, organise a meeting with the interested farmers and their families. During this meeting the extensionist should ascertain how much knowledge the villagers already have about fish farming.

After this first meeting, the extension agent should invite the villagers to visit existing ponds in a nearby village where they can discuss with the fish farmers. After this preliminary visit, the extensionist can then organise another meeting and explain in much more detail (possibly by using some audio-visual aids) what fish farming really entails (choice of the site, construction of ponds, fertilisation, etc.).

As follow-up to these meetings and field visits, some villagers will eventually ask the extension worker to visit several sites that they have identified for pond construction. It is very important, at this phase, that the extensionist makes a survey of the proposed site and decides if they are suitable, or not, for pond construction; if not he should look for a better site. It is thereafter important to fix a date for the start of the pond construction and the extensionist should plan regular visits to help and encourage the farmer, from the construction of the pond until the stocking.

4.3 Third case: No ponds exist, but potential sites are available

This case concerns villagers who have no ideas about fish farming and who have no motivation. They will not, as in the second case, make contact with the extension service, but it will be the extensionist who will have to make the first steps to contact the villagers.

The extensionist will have to organise a first meeting in the village. The best way is to have the meeting organised through the local authorities who could introduce the extensionist when starting the meeting.

The extensionist explains to the villagers what fish farming is and mentions the existing sites where ponds could be constructed. A slide projection will help to make villagers aware of fish farming. Some villagers will ask questions and the extensionist will explain the advantages of the practice of fish farming in the village:

(i) few inputs are needed, other than manual labour (family labour) for pond construction; according to experience, it usually takes between 20 and 25 man/days to construct a 100 m^2 pond;

(ii) village fishfarming is only a part-time activity for a farmer and his family;

(iii) low price fish feed ingredients and pond fertilizer are available in almost all the villages;

(iv) fish is produced in the village; there is no need for transport and fish is consumed fresh without storage problems;

(v) fish farming often leads to fuller utilisation of available land;

(vi) fish culture helps reduce animal protein deficit amongst villagers;

(vii) fish farming usually raises farmers' income.

At the end of this preliminary meeting, the extensionist should propose to visit, on the following days, the sites available for pond construction.

The number of participants during the field visit will give an indication concerning the success of the first meeting.

On the spot, at the available sites, the extensionist will explain and discuss again about pond construction, water supply canal, fertilization of the ponds, feeding of the fish, etc. He tries to convince the villagers but they are still not decided and they want to discuss the idea amongst themselves, in the village. Finally, at his next visit, the extensionist will find some villagers who have been motivated and they will want more information.

Here again, a visit to existing fish ponds in another village will allow the farmers to make up their minds. They will eventually discuss the matter in the village and at the next visit, the extensionist will find some farmers who want to start the construction of ponds.

The extensionist should then discuss the work plan and decide, with the farmers, on the date of commencement of pond construction.

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Bradfield, D.J. 1966. Guide to extension training. FAO, Rome. 169 p.

Miller, J.W. 1975. Revue et evaluation de la Vulgarisation de la pisciculture en Republique Centrafricaine. Document du Project PNUD/FAO CAF/72/002. Bangui. Mimeo.44 p.

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APPENDICES

APPENDIX I

Workshop Programme

Commonwealth Workshop on Village Level Aquaculture Development in Africa
Freetown, Sierra Leone
14-20 February 1985

DAY 1 Thursday 14 February

10.00 hours

Opening Session

Introduction of Chairman by Mr E T A Golley-Morgan, Acting Chief Fisheries Officer, Fisheries Division, Freetown, Sierra Leone

Chairman's remarks: Mr J D Sandy, Permanent Secretary, Ministry of Agriculture and Natural Resources, Freetown, Sierra Leone

Keynote address: Hon Dr Abass C Bundu, Minister of Agriculture and Natural Resources, Freetown, Sierra Leone

Address by Commonwealth Secretariat: Ms H R King, Fisheries Officer, Commonwealth Secretariat, London

Vote of thanks by Mr K A Fergusson, Acting Deputy Chief Fisheries Officer, Fisheries Division, Freetown, Sierra Leone

Consultation

11.30 hours

Topic: Aquaculture in Nutrition: General Presentation

Chairman: E T A Golley-Morgan

	Status of Food Production in Africa	*Speaker:* H R King
	Aquaculture as a Source of Food and Income	*Speaker:* B K Kamara

14.00 - 17.00 hours

Topic:	Aquaculture Practices in Africa	*Chairman:* E T A Golley-Morgan
	Systems in use and species cultivated	*Speaker:* J D Balarin
Topic:	Country Presentations	(See list of participants)

DAY 2 Friday 15 February

09.00 hours

Topic: Country Presentations (continued)

14.00 hours

Topic: Field Visit to Jui and Pamaronkho (15 miles) to observe traditional oyster harvesting and processing techniques and to observe the IDRC funded rack oyster culture project.

DAY 3 Saturday 16 February

Topic: Field Visit to Makali fish ponds (154 miles) where fish ponds of the Fisheries Division and local farmers were visited.

DAY 4 Sunday 17 February FREE

DAY 5 Monday 18 February

09.00 - 12.30 hours

Topic:	Aquaculture Practices in Africa (continued)	*Chairman:* K H Ibrahim
	Constraints inhibiting aquaculture development	*Speaker:* A B Kamara
	Technical and socio-economic factors inhibiting aquaculture development	*Speaker:* J D Balarin
Discussion:	Socio-economic considerations in village aquaculture development	*Panel:* J D Balarin K H Ibrahim A B Kamara

14.00 - 16.30 hours

Topic:	Improving Aquaculture Systems	*Chairman:* K H Ibrahim
	The economics of oyster culture in Sierra Leone	*Speaker:* Josie W Elliott
	Aquaculture development trends in Africa	*Speaker:* B J McAndrew
	Developing productive systems under village conditions	*Speaker:* M M J Vincke
	The role of extension in villag aquaculture development	*Speaker:* M M J Vincke

DAY 6 Tuesday 19 February

09.00 - 12.30 hours

Topic:	Aquaculture in Development Plans	*Chairman:* M M J Vincke
	Aquaculture Development Planning	*Speaker:* K H Ibrahim (delivered for T Gottfried Pillai)

	Logistics of aquaculture development	*Speaker:* J D Balarin

14.00 - 16.30 hours

Discussion:	Aquaculture Development Planning	*Panel:* J D Balarin K H Ibrahim M M J Vincke

DAY 7 Wednesday 20 February

09.00 - 12.45 hours

Topic:	Research in Aquaculture	*Chairman:* J D Balarin
	Overview of current research trends	*Speaker:* K H Ibrahim
	Development of indigenous species	*Speaker:* B J McAndrew
	Fish feed technology	*Speaker:* M M J Vincke (delivered for A G J Tacon)
	Aquaculture research and constraints	*Speaker:* B J McAndrew
Discussion:	Exotic Species Development	*Panel:* J D Balarin B J McAndrew M M J Vincke

14.00 hours

Review of Recommendations

17.00 hours

Closing Session

Introduction of Chairman by Mr Naib B Iscandri, Principal Fisheries Officer, Fisheries Division, Freetown

Chairman's remarks: Mr E T A Golley-Morgan

Closing address: Hon Ibrahim Sorie, Special Parliamentary Assistant

Address by Commonwealth Secretariat, Ms H R King, Fisheries Officer, Commonwealth Secretariat

Vote of thanks on behalf of participants, Mr Frank Denyoh, Deputy Director, Fisheries Division, Accra, Ghana

APPENDIX II

List of Country Papers Submitted

1. Status of Aquaculture Development in The Gambia
2. Status of Aquaculture in Ghana
3. Status of Aquaculture in Kenya
4. Fish Farming for Rural Development in Malawi
5. Status of Aquaculture in Nigeria
6. Status of Aquaculture in Sierra Leone
7. Status of Aquaculture in Tanzania
8. Aquaculture in Uganda
9. Aquaculture in Rural Development Planning, Zimbabwe
10. Aquaculture Development in Zambia

APPENDIX III

List of Participants

	COUNTRY	*NAME*	*OFFICIAL ADDRESS*
1.	The Gambia	Momodou A Cham	Fisheries Department 6 Marina Parade BANJUL The Gambia
2.	Ghana	F M K Denyoh	Fisheries Department P O Box 630 ACCRA Ghana
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6.	Sierra Leone	a) Bernis K Kamara	Fisheries Division Ministry of Agriculture and Natural Resources Private Mail Bag FREETOWN Sierra Leone
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APPENDIX IV

LIST OF RESOURCE PERSONS

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Village Level Aquaculture Development in Africa

Proceedings of the Commonwealth Consultative Workshop on
Village Level Aquaculture Development in Africa

The current status and development of small-scale village based aquaculture, particularly fish farming, in Africa, has been the subject of some discussion in recent years. Although the practice of aquaculture in Africa has ancient origins, the advancement of conventional fish farming systems is hindered by a range of technical and socio-economic factors.

In an attempt to address some of these difficulties, the Food Production and Rural Development Division of the Commonwealth Secretariat organised the consultation in cooperation with the Government of Sierra Leone in Freetown, from 14 to 20 February 1985.

The objectives were:

- To examine the technical and socio-economic factors that inhibit the successful introduction of aquaculture to rural communities in Africa.
- To identify ways and means of overcoming these problems at governmental and grassroots levels.
- To identify technical needs, including training.
- To heighten awareness amongst extensionists on the potentials of aquaculture development.

Experts in the field from Government institutions, international agencies and private consultants presented technical papers which have been edited and produced in this publication under five themes:

- Aquaculture Practices in Africa
- Improving Aquaculture Systems
- Aquaculture in Development Planning
- Research in Aquaculture
- Extension

The ensuing conclusions and recommendations were crystallized in a 10-point Resolution on Village Aquaculture Development in Africa.

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