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 molluscisides 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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