CIFA Occasional Paper No. 28 **CIFA/OP28**

ISSN 1014-2452

GUIDING PRINCIPLES FOR PROMOTING AQUACULTURE IN AFRICA: *benchmarks for sustainable development*

Copies of FAO publications can be requested from:
Sales and Marketing Group
Information Division
FAO
Viale delle Terme di Caracalla
00100 Rome, Italy
E-mail: publications-sales@fao.org
Fax: (+39) 06 57053360

GUIDING PRINCIPLES FOR PROMOTING AQUACULTURE IN AFRICA: *benchmarks for sustainable development*

by

John Moehl
Regional Aquaculture Officer
FAO Regional Office for Africa

Randall Brummett
Senior Aquaculture Scientist
WorldFish Center

Mulonda Kalende Boniface
Aquaculture Specialist/UNV
FAO Regional Office for Africa

and

André Coche
Senior Fishery Resources Officer (Aquaculture, Retired)
FAO Fisheries Department

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Regional Office for Africa, Accra, Ghana, 2006

PREPARATION OF THIS DOCUMENT

The FAO Inland Water Resources and Aquaculture Service, through the Fisheries Department Group of the FAO Regional Office for Africa, in collaboration with the WorldFish Centre, has assembled in the present document more than three decades of field-level experiences which have been distilled and reviewed to elaborate guidelines for the future development of the aquaculture sub-sector in Africa.

This document is not intended to be a work of scientific research, but rather the net outcome of lengthy processes analysing what has and has not worked as many development partners have devoted millions of dollars and person-hours to the promotions aquaculture in Africa.

This document is targeted to general aquaculture developmentalists and would-be investors. It attempts to put the sub-sector in a historical perspective to avoid falling into earlier pitfalls which may be unseen due to recurring bouts of loss of institutional memory. Using this historical angle, it reviews successes and failures and extrapolates to a list of lessons learnt. These messages are then used as the foundation of a process for elaborating national aquaculture strategic frameworks.

The document was prepared by Dr John Moehl, Regional Aquaculture Officer, FAO Regional Office for Africa, Mr Mulonda Kalende Boniface, Aquaculture Specialist/UNV, FAO Regional Office for Africa, Dr André Coche, former FAO Senior Fishery Resources Officer (Aquaculture), and Dr Randall Brummett, Senior Aquaculture Scientist, WorldFish Centre, Yaoundé, Cameroon.

ACKNOWLEDGEMENTS

The authors wish to first and foremost thank African aquaculturists for their remarkable energies devoted to establishing aquaculture enterprises for the benefits of their families. These intrepid pioneers have stayed the course in spite of often massive obstacles. As aquaculture in Africa is now coming of age and entering into a new phase of growth and investment, without the tireless efforts of these early farmers, the sub-sector would still be stuck in the quagmire of the donor-dependant seventies. We would also like to thank Dr Les Torans and Mr Henk van der Mheen whose eminent texts have been summarised in the appendices of the document as well as Dr George Chizyuka from the Agriculture Group of the FAO Regional Office for Africa who served as outside reader.

PREFACE

In August, 2003, *The Economist* wrote about "The *promise of a blue revolution: how aquaculture might meet most of the world's demand for fish without ruining the environment*"[1]. Two years later, the New Partnership for Africa's Development (NEPAD) recognised "*growing opportunities and emerging successes of aquaculture development in the region*". Aquaculture in Africa seems perched on the verge of a new era when high expectations can be matched with appropriate technologies and best practices to be able to put food on the table and money in the pocket. Aquaculture seems to have real potential and be able to realistically contribute to Africa's urgent need for significantly enhanced economic growth and food security.

This current situation is a long way from the prognosis given by FAOs *Aquaculture Planning In Africa – Report Of The First Regional Workshop On Aquaculture*, 2-17 July 1975, when it was stated: "*failures of some of the ill-conceived programmes during the early part of the century have continued to remain a major constraint in convincing the farmers and investors of the economic viability of aquaculture*". The Workshop noted that aquaculture: "*should be organised either as a government subsidised food production industry to feed the poor, like agriculture or even fishing in many countries of the world, or in the alternative as an economically viable industry that can make substantial contributions to the overall food production, economy and employment situation in the country*"[2].

Today, the option of supporting a "government subsidised industry" is a non-starter. Aquaculture is a business and must be promoted and managed as such.

It is imperative for us to take new and innovative approaches to aquaculture development if the current Blue Revolution is to succeed. We must shake off the remnants of the "state-does-it-all" approach and establish mechanisms and procedures which facilitate private-sector-led, technically sound, economically profitable, socially acceptable and environmentally sustainable national and regional aquaculture programmes.

The present document looks back at those plush days of the 70s when donor-led aquaculture programmes abounded in Africa. It extracts from these a clear suite of lessons which should guide our future aquaculture development efforts. We must heed these lessons, we must reform and adjust. The State has a key role as a facilitator and monitor. But the business of production, be it fish for the table or fingerlings for the pond, is the business of business and should be soundly put in the hands of the private sector with firm and appropriate public support.

The future is promising and holds the best rewards for those with the foresight to change for the better.

---

[1] The Economist. London: August 9, 2003. Vol. 368, Iss. 8336; pg. 20.
[2] Aquaculture Planning in Africa, Report of the First Regional Workshop on Aquaculture Planning in Africa, Accra, Ghana, 2-17 July 1975, Aquaculture Development and Coordination Programme, FAO/UNDP, Rome, September 1975. pg. 1-3.

EXECUTIVE SUMMARY

Participants in the FAO 1999 *Africa Regional Aquaculture Review*[3] were presented with a set of questions which were to be answered through the preview process:

- How much government support is enough?
- How can privatisation be facilitated?
- How can aquaculture be effectively incorporated into unified extension services?
- Should extension focus only on high priority areas?
- How can farmers receive reliable and acceptable supplies of seed and feed?
- How can the Region's training and manpower development needs be best met?
- What technologies should be promoted and how?
- How can research and extension be linked?
- How can research be re-oriented to better meet producers' needs and benefit from better information networks?

While the 1999 Review attempted to answer these questions, the operating environment seven years ago was quite different from today. Although viable aqua-businesses were only a few years away, much of the focus at the end of the last millennium was still on smallholder integrated fish farming for improved livelihoods for the household.

There is now a clear need to move beyond subsistence aquaculture and to deal with aquaculture as a business; be it a micro-, small-, medium-, or industrial-scale enterprises. This change in focus requires a shift in approach for all stakeholders. The roles and responsibilities of the public and private sectors must change significantly. Governments need to divest expensive infrastructure and undeliverable services while establishing ways and means to control quality and impact. The private sector, at all levels, needs to assume responsibilities for production of foodstuffs as well as production inputs (e.g., feed and seed). Capital will be necessary for financially viable firms and workable mechanisms for credit procurement need to be identified and implemented.

Cutting across the redefined roles of stakeholders is the issue of information in terms of quality, appropriateness, accessibility and cost. Extension is one of many information channels that are essential to the growth and monitoring of the sub-sector; but these are channels that are proving quite difficult to put in place in a satisfactory and sustainable way.

Producers themselves will need to assume progressively more responsibility for all functions including obtaining prerequisite information as well as producing quality products. Conventional wisdom places much credence on producer associations of one form or another. While it is clear that producers must work

[3] Africa Regional Aquaculture Review, Proceedings of a Workshop held in Accra, Ghana, 22-24 September 1999. CIFA Occasional Paper No. 24. Accra, 2000.

together and organise their specific functions in the overall sub-sector, mechanisms for cohesive and mutually beneficial producer groups at farm level need to be refined. Local level assemblages need to be linked to national or supra-national producer networks with adequate political voice to be able to lobby as the sub-sector evolves.

Marketing has been always formally acknowledged as a critical element of any aquaculture programme. However, in practice it has often been ignored or misinterpreted. Nevertheless, it is critical and must be carefully addressed in any and all development efforts. In general, aquaculture does not produce cheap food, albeit it has the capacity to do so in some circumstances. Given the growing supply gap for aqua-products and the much under-served intra-regional African market, it is likely that higher quality (more costly) products will dominate most of the market for some time to come.

Traditional public sector domains of research and education need also to be scrutinised. There is no doubt that considerable capacity building is needed and that education is an integral part of this strengthening. Yet, the staffing requirements from all areas are finite and raise the question of how much national agencies can invest to meet national targets. The question of weighing investment costs and outputs applies as well to research. Research is needed. It needs to be demand-driven and done in partnership with the private sector. But most research solutions have wide applicability and the economies of scale would prompt one to consider investing in regional or sub-regional research and education programmes as opposed to high-cost restrained national endeavours.

The preceding issues are inherent to any national aquaculture development programme and should form the bases for the elaboration of national aquaculture strategic frameworks which should guide the development of the sub-sector. A strategic framework is founded on the principles of comparative advantage – in other words, do things where they have the best chances of success and have them done by people who have the most vested interest combined with best technical ability.

In this approach, the starting point is the idea of "**clusters**" of activity. There are economic and production thresholds below which public or private support are not warranted. These thresholds, or production minima, correspond to a given level of effort – be it number of farmers, area in production or tons produced. Above this threshold, aquaculture becomes commercially feasible, while below, it is more of an adjunct and non-commercial undertaking.

The ability to establish a cluster depends upon the bio-physical and socio-economic parameters of any given site; sites that have the ability to "house" a cluster would be considered as **high potential zones** for the specific aquaculture production system in question. High potential zones for each appropriate production system should be the areas of concentration of effort from both the public and private sectors.

The concepts of clusters and high potential zones are the core of the philosophy guiding the national strategic framework. Limited human and financial resources no longer allow governments to provide all services to all people. Efficiency and improved returns on investment require public agencies to invest where there is realistic potential. These same imperatives require government to retool and redefine its role, including the role of being the steward of an iterative and broad-based national strategy which guides the evolution of the sub-sector.

However, negative inertia and outmoded ways of doing business continue to confront developers. Change is often not easy, particularly when some perceive it as adversely affecting their lifestyles. Thus, while the public sector should have an intrinsic stake in elaborating and implementing national strategies, in the short-term, this may sometimes not be the case.

This lack of buy-in from the relevant public institutions should not be seen as a do-or-die conundrum. With a strategic approach founded on the principle of sustainable commercial aquaculture, the private sector should be aware that it has an equally innate advantage is achieving a functional and workable national strategy to guide the sub-sector's development.

In 1999, a United States fish farmer commented on the falling market prices: "*The failure stories about tilapia farming are terrible. People loosing their life savings and going bankrupt. It's so sad. And it's sadder still that we who are in the industry don't do more to prevent it. Put out the word. Aquaculture is not for the faint of heart or for the financially weak. It's a tough business and tough to make a living at, forget about making money.*"

Aquaculture can contribute to national policy objectives, stimulate investment and help fill the expanding aqua-products gap. Furthermore, the Third Millennium may well herald the Blue Revolution for Africa. But it will not be easy: aquaculture is tough business.

Aquaculture development in Africa is chronicled in *An indexed list of FAO publications related to aquaculture, 1964-2005 FAO Fisheries Circulars* - C924, Rev.2 published in 2006. 111 pages. ftp://ftp.fao.org/docrep/fao/009/a0524e/a0524e00.pdf with additional publications listed at http://www.fao.org/fi/eims_search/publications_form.asp?lang=en

TABLE OF CONTENTS

PREPARATION OF THIS DOCUMENT — *iii*

ACKNOWLEDGEMENTS — *iii*

PREFACE — *iv*

EXECUTIVE SUMMARY — *v*

WHY "GUIDING PRINCIPLES" — *1*

INTRODUCTION — *1*

- **Aquaculture: What is it?** — 3
- **Definition of Terms** — 3
- **Chronic Constraints** — 4

LEARNING FROM THE PAST — *5*

- **What Went Wrong** — 5
  - *Project Design* — 5
  - *Technology* — 7
  - *Targeting* — 15
  - *Conclusions* — 17
- **What Went Right** — 18
  - *Critical Mass* — 19
  - *Integration* — 19
  - *Extension Model* — 20
  - *Sharing Knowledge* — 23
  - *Production Systems* — 25
  - *Conclusions* — 28

OPPORTUNITIES IN THE THIRD MILLENNIUM — *32*

- **The Need For National Strategies** — 33
- **Priority Setting** — 35
- **Strategic Approaches** — 37
  - *Seed* — 37
  - *Feed* — 38
  - *Credit* — 39
  - *Marketing* — 39
  - *Information* — 40
  - *Education* — 40
  - *Research* — 41
  - *Cross-cutting elements* — 41
- **How To Implement A Strategy?** — 42
- **Best Practices** — 43
- **Regional Issues** — 43
- **Risks** — 44

CONCLUSIONS & RECOMMENDATIONS ______ *46*

WHAT NEEDS TO BE DONE? ______ *46*

Governments ______ 47

Industrial Producers & International Investors ______ 48

Small- & Medium-Scale Commercial Producers ______ 48

The Non-Commercial Segment ______ 49

Service Providers ______ 49

Civil Society ______ 50

International Community ______ 50

Appendix I: 1999 Africa Regional Aquaculture Review -- Executive Summary: ______ *52*

Appendix II: Limbé Declaration: ______ *55*

Appendix III: Elements of the Cameroon Strategic Framework and the Role of Public and Private Sectors ______ *57*

Appendix IV: The NEPAD Action Plan for the Development of African Fisheries and Aquaculture ______ *63*

Appendix V: Case in Point – Aquaculture Development in the Lake Basin Area of Kenya ______ *70*

Appendix VI: Review of Aquaculture Extension in the Africa Region ______ *81*

Appendix VII: Field Notes for African Freshwater Aquaculture ______ *89*

Give someone a fish and they will have a meal.
Teach someone how to make money raising fish and many people will have many meals.
[modification of oft-cited "aquaculture proverb"]

WHY "GUIDING PRINCIPLES"

Aquaculturally, the Africa Region is quite homogenous. This homogeneity is not in terms of social structure, climate or economic environment; it is with regard to the general level of development. Most of Africa has an under-developed aquaculture sector. The paltry contribution of Africa to the global aquaculture harvest is well documented and will not be further addressed in this document. However, the newness of aquaculture in Africa means that most countries are on similar footings; sharing analogous constraints and comparable opportunities.

This similarity is further exemplified by the relatively narrow range of culture systems and organisms. Clariid catfishes and tilapias account for the majority of finfish culture; generally raised in ponds, but with growing use of tanks and cages. Throughout most of the region, these culture systems benefit from the comparative advantages of reasonably cheap land and labour; frequently combined with available and affordable water.

These commonalities denote a situation where, to a large extent, common solutions can be applied to common problems. This is not to be confused with a "cookbook approach" where pre-determined and prescriptive technology packages are proposed. The similarity suggests rather that **mutual methodologies** can be applied to parallel subjects; these adjusted and adapted to specific circumstances.

The approaches to these mutual methodologies are embodied in guiding principles: broad-spectrum canons that can orient national development programmes. These principles serve as reference points which can facilitate the evolution of the developmental processes and circumvent costly preparatory activities, without repeating errors of the past. They serve as a generic road map which is built on three decades of experience and reflects wide-spread consensus as to best practices.

INTRODUCTION

Aquaculture, in a classical sense, is an introduction to Africa. Traditional aquacultural systems, including whedos, acadjas, howash and others, have been used for centuries and are integral parts of customary food production or procurement practices. These techniques, however, are extensive and highly dependant upon unencumbered access to environment goods and services; access which is under increasing pressure from growing populations and competition for resources. Hence, although important at community and family levels in many instances, these time-honoured ways are in decline and have little potential to make significant contributions to national fish supply.

It is introduced production practices that have the potential, albeit still largely untapped, to add appreciably to national fish supply. These are principally pond culture systems introduced over five decades ago as sources of high protein food. Early, mostly colonial, advocates saw lush tropical climates as the ideal environments for raising tons of fast-growing African fishes, providing cheap food for labourers and the underprivileged.

This initial justification persisted for several decades as aquaculture, chiefly fish farming, was seen as an “easy” way to make use of available resources through the construction of family fishponds for food and income. Success stories included families using money from fish sales to pay school fees or purchase roofing materials as well as having highly-prized food for celebrations. These fishponds were stocked with locally available species which were fed household scraps and by-products from other family farm enterprises. Family fish farming became the centrepiece of most national aquaculture development programmes in Africa in the 1970s, and continues today as one of the frequently encountered reasons for supporting aquaculture.

In the 1980s, the family fishpond component of national programmes was, in some cases, complemented by larger-scale production using a variety of systems including, among others, commercial-scale pond-based farms in Nigeria and Malawi, raceways in Congo and Burkina Faso, cages in Niger and Côte d’Ivoire along with tanks in Zimbabwe and Kenya. However, within a decade many of these larger enterprises had failed and family production remained the mainstay of most programmes; these heavily subsidised by donors.

When family fishpond aquaculture failed to meet expectations for improved food security and economic growth, international aid donors became widely disenchanted; regardless of whether these expectations were realistic or not. Farm-raised fish continued to make minimal contributions to national fish supply, farmers continued to rely on external support and national institutions continued to have difficulty supporting the sector. By the mid-1990s, bi- and multi-lateral support to aquaculture in Africa hit all-time lows as the balloon of the aquaculture miracle burst and national programmes slumped without their accustomed extra-budgetary support from donors.

This slump effectively crippled national programmes in many countries. National infrastructure and services shrivelled, generally atrophying to unusable levels. Farmers, who had become attuned to a high degree of public assistance, either abandoned their ponds or allowed them to revert to a near-natural state. Government agents, no longer receiving emoluments from donor-driven interventions, stopped going into the field. Government agencies were further weakened by the combined and growing effects of HIV/AIDS, a brain drain to the African Diaspora and early retrenchments resulting from declining national budgets.

Paradoxically, as public services reached their nadir, a second wave of private sector aquaculture investment arose in some countries. By the close of the 20th century, private-sector-driven enterprises had established firm foundations in, to name a few, Zambia, Zimbabwe, Nigeria, Madagascar, South Africa and Côte d'Ivoire. These new firms included not only the oft-seen tilapia and catfish systems but also mariculture with the lead being taken by Madagascar for shrimp and South Africa for molluscs.

With the arrival of the new millennium, aquaculture in Africa seems perched on the verge of a favourable future. There are new and realistic understandings of what aquaculture can, and cannot do. There is a new, and often dynamic political will. There is high demand for aquatic products and an invigorated investment environment. But, there is also a loss of institutional memory and an abundance of misinformation concerning the pragmatic contribution of aquaculture to national economies and market baskets. For this bright future to become a reality, one must heed lessons learnt and approach aquaculture development strategically and sensibly.

Aquaculture: What is it?

A number of descriptions of aquaculture exist and have often been the subject of academic discussion as to their thoroughness in encompassing the sector. For the purposes of the present document, aquaculture will be considered as any of the various **aquatic production systems** which are under the control of the producer for any part of the production cycle and which produce a crop which is "owned" by the producer (ownership, corporate or individual, applying to both formal and traditional rights to the produce).

Definition of Terms

Any discussion of aquaculture development must use specific terminology for which there is mutual understanding as to its use and content. A key issue is the classification of different levels of aquacultural production. Various authors have chosen barometers of intensity: extensive, semi-intensive or intensive. Some have preferred delineation based on size: small-, medium- or large-scale. Other adjectives that have frequently been used to categorise various modes of production include urban, peri-urban, rural, smallholder, subsistence, middle-income, emergent or peasant.

In concert with prevailing terminology, the following discussions will classify production as being **commercial** or **non-commercial**. The distinction between these two management styles is not always clear-cut, but the overriding indication is that the former is managed as a for-profit business with the producer investing capital in the enterprise, and cash returns on investment the main criterion of success. Commercial aquaculturists are active players in the market economy. They purchase inputs, including labour. Commercial operations can be of any scale (small, medium or large), even micro-enterprises. Commercial firms can be urban, peri-urban or rural; their sites determined by the most profitable location as decided by the operator.

A subset of the commercial category is **industrial** production. This level of management fulfils all the prerequisites of commercial operations, but is undertaken on a larger scale. Industrial operations are much less dependent upon public sector support, relying predominately upon an enabling environment to muster substantial private investment. These firms have adequate capital resources to ensure the supply of all needed inputs including information (technical assistance). Accordingly, industrial operators would most often not be the direct beneficiaries of public sector promotion and support efforts.

Non-commercial farmers are not farmers who do not want to make money from their fishpond or other production system. It goes without saying that all farmers would make money if they could, and most non-commercial producers do sell part of their crop. However, these farmers do not manage or invest in their aquatic resources as a business. Their aquatic production is a part of a complex mosaic of farming systems which are complementary and risk-reducing. Their aquatic produce is important for home consumption as well as being a "bank" where a sellable product is available when needed; a product that comes in small packages and allows the farmer to have quick access to small amounts of cash as opposed to selling another more expensive item (e.g., goat or chicken). As with the alternative, non-commercial production can be of any scale as well as being urban or rural.

This dichotomy may appear convoluted and full of contradictions. Admittedly, it is somewhat subjective, but it represents the present conventional wisdom as to how to conceptualise different levels of production; in the over-view, based on the producers' motives more than the technology applied. It has been suggested that the commercial group represents fish farmers while the non-commercial group consists of farmers with fishponds.

Another area of controversy in regard to choice of terms is with respect to **policies**, **strategies** and **plans**. For the purposes of subsequent discussions, <u>policies</u> are considered as high-level (macro) objectives and goals. It is understood that most, if not all governments have policy objectives (e.g., eradication of poverty, accelerated economic growth, improved equity, etc.). A <u>strategy</u> is the pathway by which policy objectives are achieved; a set of tactics along with designated roles and responsibilities which define processes to be employed in reaching the designated goals. Strategies are plastic, flexible and iterative, changing to meet new conditions. <u>Plans</u> are specific descriptions of activities to be undertaken within the context of the strategic pathway. Plans are implemented over a fixed time and area and, once completed, are replaced by a new plan.

<u>Chronic Constraints</u>

For at least the past three decades there have been periodic reviews of the status of aquaculture in Africa; each trying to identify the key reasons for its lack-lustre performance. While different reviewers have had different perspectives as to the root causes of the poor results, in spite of significant overall investment, there have been five common cross-cutting factors. These omnipresent constraints are: (i) lack of good quality seed; (ii) lack of good quality feed; (iii) lack of capital; (iv) lack of access to appropriate information; and, (v) lack of markets. In the aggregate, these "big five" affect aquaculture development as much today as they did in the 1970s.

LEARNING FROM THE PAST

Aquaculture in Africa has almost been a mystic endeavour. With near pious fervour, enthusiasts have lobbied for support to the sub-sector; often in the complete absence of any tangible benefits. Accordingly, as with many enigmatic ventures, when disappointment struck, there was a negative backlash – aquaculture transformed from a panacea to a pariah.

Today we have the extravagance of analysing past efforts without suffering the trials and tribulations experienced by those who were first attempting to make the sector work. Unfortunately, much of this analysis is done in the abstract without the benefit of the first-hand accounts of preceding actors. In fact, as previously mentioned, there has been an acute loss of institutional memory over the last 20 years which makes learning from the past that much more difficult and important.

If the present is a reflection of the past, the present situation for most national aquaculture programmes in Africa could be typified by several thousand, widely dispersed family (non-commercial) fishponds producing 500-1 000 kg/ha/yr, at best. To this can be added varying, but increasing, amounts of contemporary commercial production from a combination of small-, medium- and large-scale producers.

Consequently, many national aquaculture programmes are comprised of two parallel components corresponding to commercial and non-commercial production systems. Future efforts to establish productive and sustainable national programmes must take into account this dual architecture from the perspective of what historically did or did not work.

The following two sections will highlight experience gained from field-level aquaculture development efforts over the past thirty-five years: those actions that did not foster sustainable results, although they expanded the knowledge base; and those actions that produced enduring results and which now form the foundation of many of today's development strategies. These generalities will be complimented by specific examples of aquaculture projects and producers, presented in boxes. Following these discussions, the experiences will be synthesised into a succinct list of lessons learnt.

What Went Wrong

Project Design

At the onset, there was practically universal acceptance that aquaculture was a good idea. Having a pond in and of itself was often considered as a worthy accomplishment, irrespective of its true costs and benefits. This phenomenon was witnessed by the fact that many early projects targeted numbers of ponds and farmers as opposed to the production from these units: quantity vs. quality.

Figure 1: Abandoned and semi-abandoned government fish stations can be found in nearly all countries. Unless divested, they pose a drain on public coffers, a poor use of resources and sometimes a public health risk (Madagascar).

Many development efforts focused on institutional strengthening and capacity building. The normal approach was to support the appropriate government agency and subsidise the services it provided to the aquaculture sector. At field level, this often meant building public infrastructure; supporting a series of government stations, hatcheries or centres, which planners hoped would serve as hubs around which aquaculture would develop. Stations were to provide inputs (seed and frequently feed), be the base for extension support, serve as training and demonstration centres, undertake research and produce food fish (and other produce) for sale to offset operating costs.

Along with establishing infrastructure, this approach also entailed the training and equipping of extension agents to undertake what has been widely referred to as the Training & Visit (T&V) extension system, in which the extension agent receives training from a subject matter specialist housed at the extension headquarters and then transfers the knowledge gained through periodic farm visits.

These agents were most often “dedicated” extensionists – specialists working only in the field of aquaculture as opposed to agriculture generalists. Equipment included a means of transport, whether a bicycle or motorcycle. Freshly trained and equipped aquaculture specialists would be based at a station and assigned an extension “zone” which could have a radius of more than 50 km but include fewer than 20 practicing fish farmers.

This “station & motorcycle” approach was used in more than 20 African countries. In all cases, it proved to be unsustainable. The recurrent costs were simply too high. Although increased production, and certainly increased participation could be directly attributed to the presence of the extensionists, in the absence of donor funds, government agencies were unable to provide adequate budgets to keep stations functioning and agents moving. These interventions left in their wake a large number of widely dispersed family fishponds which were difficult, at best, to monitor.

“Dedicated” aquaculture extension services are expensive and, in most instances, inefficient means for assisting far-flung fish farming families. In theory, the marginal increase in fish production attributable to extension support should be several times more than the cost of providing this service. In reality, many dedicated aquaculture extensionists worked in zones where the value of fish produced was a fraction of the service cost.

Transport has been one of the main linchpins in extension delivery. With low farmer density, either due to lack of sites or lack of interest, single agents must cover large areas requiring motorised transport, including fuel as well as maintenance costs. With higher producer densities, bicycles have been proven as successful means of transport. But bicycles also require spares and maintenance. Some pioneering projects have stockpiled spares and provided upkeep training for agents, but ultimately have still been faced with the scenario where the agents were immobile due to a lack of functioning transport.

Figure 2: In struggling national programmes, private facilities also vacillate between periods of activity and inactivity; each renewed spurt of effort requiring considerable cost to get the farm back into an acceptable state where a crop of fish can be raised (Madagascar).

Aside from its practical financial limitation, there was also a fundamental flaw in the “station & motorcycle” approach; it addressed principally the interests and prescriptions of government and donors and was not suitably sensitive to the desires of farmers, or requirements for sustainability.

It is now widely accepted that any innovation must be economically viable, socially acceptable and environmentally friendly if it is to be sustainable and an asset to the overall “public good”. However, two decades ago farmers were asked to adopt aquaculture because it was “a good thing”; its economic comparative advantage, social compatibility and environmental suitability being unknown or unproven.

Technology

At the farm level, many interventions stressed self-sufficiency, where the farmer became autonomous from uncertain government support; producing seed, using on-farm feed and selling (if at all) to rural neighbours on the pond bank. Extension support to these farmers was seen as catalytic; after several years of direct assistance and training, the farmer was weaned of external help and expected to become a stand-alone fish producer. Through the benefits of training and extension support, it was also expected that these farmers would become more and more astute; each subsequent harvest being better than the one before.

Box 1 US Peace Corps: Starting in the late 1960s, the Peace Corps posted aquaculture volunteers in Africa. At its zenith, aquaculture volunteers were working in more than 10 countries. Volunteers were trained as self-contained "mini" aquaculture extension services. The underlying principle was that government agencies were too weak to be able to provide meaningful extension support. Consequently, volunteers were initially programmed to work directly with farmers, teaching the farmers how to do basic fish farming. It was felt that several years of volunteer assistance would lead to self-sufficient fish farmers who did not need further government support; farmers who produced their own seed, used on-farm feed and sold their fish on the pond bank or ate them with the family. At the onset, volunteers had motorcycle transport and we able to cover relatively large geographic areas; not infrequently more than 2,000 km^2. As the programme and host institutions evolved, many volunteers shifted to working with national counterparts; most often government aquaculture extensionists who had a secondary education and some specialisation in aquaculture from technical schools or training centres. The first volunteers had general Bachelor of Science degrees and received intensive 12-week training on fishpond construction and management. With time, budget constraints necessitated shorter and shorter training and volunteers become more generalists; also exchanging their motorcycles for bicycles due to fear of road accidents. At present, the sole remaining significant Peace Corps aquaculture programme is in Zambia, with a much smaller effort underway in Ghana. Over the years, Peace Corps successfully demonstrated that motivated people with very basic knowledge could make an impact in terms of transferring aquaculture technology in a sustainable way. Follow-up reviews after the closure of volunteer posts have demonstrated that for years following the departure of the last volunteer at least some of the farmers who had worked with the volunteers continued to raise fish. However, the cost of this technical support is very high – often more than five person years of effort to develop a sustainable group of 10-20 farmers. The volunteers, almost by definition, worked on the fringes, or even outside the formal government structure. This may have been appropriate decades ago, but clear links to the public sector are now needed as well as assurances of value added. The Peace Corps also demonstrated the critical importance of technically sound postings. When political imperatives overshadowed technical prerequisites, volunteers were assigned to nonviable posts to the frustration of all. To a large extent, the achievements of the Peace Corps programme, in spite of its weaknesses, can be attributed to its social and not technical soundness: volunteers integrated into local communities and had ample time to work intimately with farmers and their families. The programme contributed considerably to the multitude of family ponds scattered across the landscape, but rarely had a cohesive strategy or business orientation – to the point of commonly not encouraging record keeping or doing any reporting. Additional details concerning the Peace Corps/Congo programme are presented in Box 3.

However, as results from the field became available, it was apparent that there was no progressive increase in yield, the first harvest often having been the best due to a combination of factors including high motivation by a new fish farmer, high background fertility from the newly denuded ground and relatively high(er) quality fingerlings provided from the government station.

Since on-farm inputs were the major nutrient sources, these were greatly dependant upon the availability of time to gather them. Excited new farmers spent more time in collecting inputs than their seasoned, and often jaded, counterparts. Thus, new ponds tended to have better management and more food available.

Figure 3: Small family operations can require considerable maintenance and, unless well managed, can be a poor use of resources in areas where land and water resources are limited (Madagascar).

Attempts to enhance the availability of on-farm inputs included encouragement of “integrated aquaculture” where complementary enterprises such as poultry or pig husbandry were undertaken in conjunction with fish raising. In many cases, the animal husbandry units were actually built above fishponds so that excreta and other wastes automatically fell to the pond for the fish’s benefit. Although these systems were *sensu stricto* more associations than integrations, they attempted to make more nutrients available with less labour input. But, most did not succeed.

Problems in *fish-cum-chicken*, *fish-cum-duck* or *fish-cum-pig* associations were not generally biological; barring disease, the linked animals grew and the fish did benefit from the automatic manuring, significantly increasing yields. The problems were socio-economic: managing multiple enterprises more intensively required greater resources, skill and markets for the increased production – requirements not easily mastered by most farmers without external support. Anyway, animal feeds and medications still had to be purchased or collected locally, doing little to alleviate the original problem of input shortages.

Figure 4: For many ponds scattered around rural areas, it is difficult to know if the pond is active or abandoned (Cameroon).

As the limitations of on-farm nutrients became increasingly apparent, some projects invested effort in systems that relied on supplemental feeds in the form of brans, brewery wastes, oilseed meals and other agricultural by-products. However, these were inevitably subsidised as raw material and transport costs were such that, given low yield levels, most farmers would not be able to pay their full price. Likewise, few other inputs such as lime or inorganic fertiliser were used due to their costs vis-à-vis the low level of productivity of most aquaculture systems.

Figure 5: Most ponds are hand dug. Although most claim to use "cut-and-fill" technology, inevitably the dirt is heaped at the closest location and rarely compacted. The result is a leaky pond with too much levee on the shallow side and too little on the deep end (Cameroon).

Standard techniques included harvesting ponds by draining. As most farmers did not have nets, baskets were used to cover the drains and, as the pond approached empty, "fingerlings" (e.g., 5-10 g fish), normally of tilapia, were captured from the mud and transferred to small holding ponds nearby where they would be kept while the pond bottom was dried and any maintenance done, after which time they would be used for re-stocking the pond. Not only did poor handling result in weak fish that seldom survived more than a few days, these "fingerlings" were often sexually mature fish which began reproducing within days after re-stocking; the pond quickly reaching carrying capacity.

Tilapia was considered as the "wonder fish" that would suffer all varieties of abuse and still produce good results. The chief drawback was long acknowledged to be the tilapia's tendency in ponds to mature early and spawn (often at less than 30 g), upsetting planned stocking and feeding strategies. Early solutions to this problem relied on predators to control over-reproduction or hand sexing to obtain a (nearly) all-male population and thereby greatly limiting recruitment.

Figure 6: The apparent advantages of building poultry or pig houses over ponds were quickly adopted in many areas. However, the costs of building and maintaining the poultry enterprises were often high and the farmers reverted to a free-range style (Cameroon).

Catfish of the genus *Clarias* were of initial interest, not as a primary culture species, but as a predator on unwanted tilapia fry. The first challenge for catfish culture was controlled spawning, followed closely by problems of low fry survival. While considerable progress was made in identifying appropriate technologies to resolve these challenges, technology transfer to the private sector was difficult and catfish remained a minor culture species in much of the region.

As catfish languished in the background, governments and farmers searched aggressively for "better" fish to replace tilapia. Chinese carps were introduced into several countries in the hopes of superior performance. In many cases, the mono-climatic tropical environments did not provide the needed triggers for reproduction and carp spawning became a new challenge. As with catfish, induced spawning through hypophysation enabled the production of carp in Nigeria, Cameroon, Mozambique, Rwanda, Kenya and Uganda, to name a few countries that at one time had high expectations for these Asian introductions. The most notable, and successful, introduction was in Madagascar (see following section).

Box 2 Central African Republic: From the 1960s, the Central African Republic (CAR) served as the headquarters of a regional FAO project covering Central Africa. This programme was housed at a major fish station in each participating country (e.g., Djoumouna in Congo, Lanja in CAR and Foumban in Cameroon). These government stations played the critical roles of the time: training, demonstration and input supply. The regional programme began tapering off in the 1970s but the national programme remained into 1990. During this period, the national programme also received support from a number of other partners including Peace Corps and the United Nations Children's Fund, UNICEF. At its pinnacle in the 1980s, the CAR programme was reported to be one of the "best" in Africa: there were thousands of fishponds reporting very high yields, in some cases more than 4 t/ha/yr. A state-of-the-art *Clarias* catfish hatchery had been built and was producing large quantities of fry. A great variety of training, educational and technical materials had been prepared including thorough economic analyses of the systems being promoted (*fish-cum-chicken* prominent among these). A network of public hatcheries had been built, a programme of credit put in place and extensionists (*moniteurs piscicoles*) trained. There was even a programme for Farmer Leaders, where better farmers were given a stipend and bicycle to provide extension support to their nearby colleagues. However, within 10 years, the programme was in decline due to a combination of natural and political misfortunes. Drought led to the drying-up of ponds, economic woes led to the inability of government to support a programme that relied nearly completely on extra-budgetary funds. Catfish fry could not be distributed from the central hatchery due to budget restrictions. The Farmer Leaders spent more time lobbying to be integrated into the civil service than in helping their neighbours. Peri-urban fish/chicken producers found themselves in direct competition with politicians who prioritized their own fish farms within the programme, and dropped out. Credit schemes had nearly a zero repayment rate. And, cottonseed meal, the previously free input which had facilitated good yields, now came into short supply as cotton gins closed and market competition from cattle producers increased. The downward trend has continued and aquaculture as an active rural or peri-urban programme has nearly ceased. Some farmers continue to raise a few fish in small poorly managed ponds, but the programme's momentum is lost. Nevertheless, it did achieve important results in terms of developing a catfish spawning programme and generating a wealth of information on many aspects of aquaculture development, much of which is still relevant today. The programme stimulated great enthusiasm among participating farmers, some of whom had commercially viable fish farms. The programme ultimately demonstrated that impressive short-term outputs can finish as disappointing outcomes without inherent sustainability based on a solid and economically viable private sector foundation, which can function independently of the vagaries of public sector politics.

Box 3 Zaïre, Projet de Pisciculture Familiale (PPF): This joint USAID/Peace Corps project started in the late 1970s. At that time, the project was unique in the sense that it based its extension model on the premise of income. Since many cash crops in central and west Africa are seasonal, most farmers do not have a guaranteed source of regular monthly income. Yet, a fish farmer with six ponds growing tilapia on a six-month cycle could harvest and sell every month. The project was also innovative in providing a degree of planning to Peace Corps service that had heretofore been unknown; volunteers were programmed to work at a post for six years – three two-year terms – each term having an exclusive job description to try and avoid the conundrum that the first volunteer at a post was perceived as having the best job because this was when everything was fresh and new and no one was following on the shirt-tails of a some one else. This "Triple Six" (i.e., six ponds for six months with six years of support) approach was novel and an indication of how hard many people were trying to make aquaculture work. However, in spite of the best intentions, sustainability was still an issue. While the six-pond-model made perfect sense, it did not take the farmer's opportunity cost into account. In mixed cropping systems, farmers carefully allocate time to all activities including leisure. It was discovered that, in most cases, the amount of time a farmer allocated to fish farming was not proportional to the number or size of ponds (i.e., a more-or-less fixed amount of time was budgeted for fish). With organic fertilisers as the major nutrient input, input requirements for six ponds are significantly greater than for one or two ponds. Moreover, the greater the requirement of input the greater the requirement of time since most organic fertilisers were gathered and prepared from on-farm or near-farm sources. In the end, the farmer generated a fixed quantity of input based on the fixed availability of time; this quantity used for the ponds – be they two, four or six. This meant that the greater the number of ponds the lower the per pond productivity. More ponds allowed for better scheduling of harvests but the overall farm fish production was nearly the same regardless of the area in production. The six year volunteer model was more successful although at times difficult to apply. The allure of being the first volunteer at a post was difficult to dispel and it was sometimes politically difficult to keep volunteers at a post for six years or, conversely, to move them out after six years. The biggest issue, in retrospect, was that the farmer was the volunteer's counterpart and the volunteer was outside of, and independent from any public sector structure. Even if these public structures were fragile and at times disjointed, long-term sustainability required stronger ties with government.

The search for the ideal culture species continued, using both alien and indigenous species. Numerous native cichlids were cultured on research stations and other facilities. *Labeo*, *Lates*, *Bagrus, Macrobrachium*, *Heterotis* and a wide assortment of other African aquatic genera were scrutinized for their potential in aquaculture. Channel catfish, Indian carps, American crawfish, trout and bass were among the plethora of alien species imported with little forethought, and often serious negative environmental consequences, in hopes of finding the ideal culture species for Africa.

This process has resulted in wide transboundary movement of genetic material. Although this may have been admissible one or two decades ago, conservation of biodiversity is now an essential ingredient in all development efforts. Numerous international covenants and conventions exist to control the movement of genetic material. Unfortunately such agreements are more easily endorsed than implemented and many private fish farmers continue to import species without adequate controls.

> *Box 4 White Elephants*: It may seem as though most of the unsustainable early efforts were related to development projects and programmes involving international donors and host governments. Nonetheless, the private sector was equally prone to commit what today are viewed as *faux pas*. People from Burkina Faso to Nigeria and Congo, to name but a few, were ready and willing to buy into the alleged aquaculture miracle. Whether as a private sector initiative or a parastatal firm, large investments were made in fish production systems that may have benefited the promoters or middle-men, but that produced pitifully few fish. Among these were various, relatively hi-tech systems including raceways and recirculating units which were poorly conceived and sited in completely unsuitable locales. In some extreme cases, governments were repaying loans for these monuments years after they had been abandoned. They remain painful lessons as to the importance of understanding the technology and being able to apply it in the suitable economic environment.

In the final analysis, it was not the fish, but its management in culture that was the central issue. As time passed and national programmes matured, production per farm rarely increased. In fact, it often decreased. In spite of new culture organisms, improved technologies, better training and extension support, there were still diminishing returns.

It became clear that for systems relying on on-farm inputs, the primary investment on the part of the farmer was time; and farmers would typically only invest a certain amount of time in fish farming, as other activities competed for the family's labour resources. Thus, nutrient input level was tied to time availability; the latter being often in short supply. Harvests remained low and the poor quality of seed meant that average size at cropping was small.

Nonetheless, farmers were repeatedly led to believe that "good" farmers should be able to get harvests with an average size tilapia of 300-400 g. This was what farmers expected, but mixed-sex tilapia systems based on on-farm inputs were hard pressed to routinely produce this size fish, even with good management, and certainly not with the level of management that prevailed in most locales. Furthermore, it has been well documented that producing the smallest acceptable size fish is the most profitable production strategy. Nevertheless, people still tried to grow the biggest fish they could.

Even when producers managed to overcome these many technological barriers, marketing of the fish was largely ignored, most commonly because of high demand for fish within the local community. This approach turned out to be highly de-motivating. Most of the farmers who succeeded with aquaculture did so out of a strong desire to better their lot, both economically and in terms of household food security. African traditional social security systems mitigate against this. Successful farmers are under extreme pressure to share their fish with the village or at the very least, sell them or, more typically, barter them at charity prices.

Box 5 Rwanda Projet de Pisciculture National (PPN): In the early 1980s, PPN was one of the last big national aquaculture projects. Funded by USAID, this project aimed at establishing a viable government-led fish farming programme. While its design was typical of similar efforts elsewhere (i.e., build a government training centre, renovate government infrastructure including regional hatcheries, train and equip dedicated aquaculture extensionists and develop a cadre of technical management through overseas training), it was ambitious in the sense that it undertook these activities in a high altitude country with the highest population density in the region. After a five-year period of implementation, the project was bestowed with accolades; 7,000 families were growing fish in ponds, supported by 55 recently-trained extensionists and eight extension supervisors. Five local hatcheries were producing quality tilapia seed, using tools and methods developed by the project. Overall, family fishpond production increased by 425%, with 20 percent of farmers producing 2,000 kg/ha or more by the end of the fifth year. The project attempted to learn from past experiences and adopt a practical approach; bicycles and not motorcycles were used by extension agents who had a fixed schedule of visits based on a pre-established calendar that facilitated supervision. Technology transfer was periodically monitored by an objective survey instrument which attempted to quantify the adoption of new practices deemed appropriate for the high altitude, cool climate. Survey results were analysed and used to revise training curricula. However, the subsequent political turmoil endured by the country not withstanding, in spite of all efforts to the contrary, the project was likely destined to leave an unsustainable government structure in its wake. Symptomatic of the prevailing project approach, extensionists and their supervisors received indemnities and/or other perks paid by the project. Hatchery, extension and training materials were imported using project funds. Operating costs were born by the project. In short, in classic donor dependency style, the post project structure was based on procedures and processes elaborated during the project and financed by the donor – procedures and processes that could not be born easily by the government, even in the face of convincing arguments. The project had comprehensive data documenting costs and benefits and was able to show that each dollar invested produced more than two dollars worth of fish. But, this level was not sufficient to attract long-term support; some saying a multiplier factor of 5-10 would be needed if government were to divert resources to the post project phase.

Even if this exchange has positive, if non-fiscal, benefits for the community, incentives for a poor farmer to continually subsidize less productive neighbours are low. Additionally, when cash or commodities are traded only within a local economy, there is no net gain in village wealth (unless the village begins printing its own negotiable currency, which is generally frowned upon by government). For the village to actually become richer, it must trade commodities with the outside world.

Many embarked on aquaculture schemes without even looking at the external market. When they did, many discovered that their produce was more expensive than other fish on the market. Cheap imported frozen products combined with periodic high-season flooding of markets from local capture fisheries meant that few farm-raised products could compete unless they were sold as luxury items.

Targeting

While productivity and individual fish size did not increase as anticipated, expansion in number of ponds or number of farmers was also not as expected. Expansion in some areas had noticeable limitations in terms of suitable land or available water which imposed ceilings on aquaculture expansion. In addition, aquaculture projects often targeted the wrong audience. While traditional or political leaders were often the first to express interest in building a pond, their motivation was frequently not for profit or food but rather prestige or amusement. Accordingly, emulation by the population as a whole was minimal. Just as a public facility was not the best demonstration since farmers knew that governments had means that greatly exceed their own, the local elite also were seen a part of an exclusive class whose activities could not easily be replicated by the "common man".

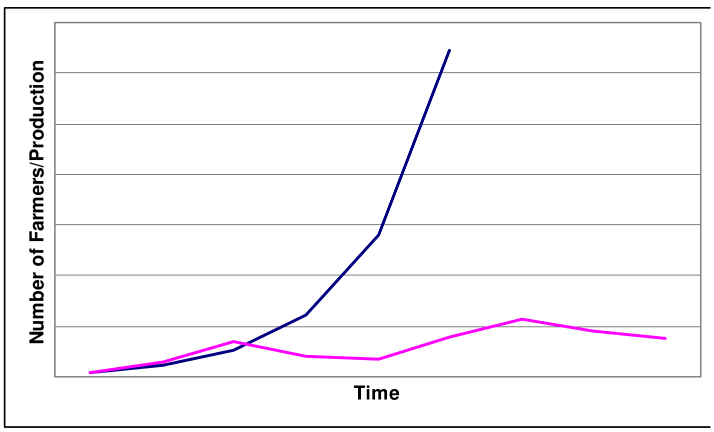

Figure 7. Anticipated (blue line) Vs realized (pink line) trends in African aquaculture development. Planners envisaged more or less logarithmic growth. More typically, once a project ends, adoption and production decline. Each successive project gradually increases production, but much more slowly than planned.

Errors in targeting included a focus on communal aquaculture. Although group labour unquestionably relieved the drudgery of building ponds and dams, and also may have addressed issues surrounding the access to, or use of common property, it was most often an unsuitable management choice. When it came to managing the pond, every one wanted some one else to take the responsibility. When it came to sharing the harvest, every one wanted the choicest items. This was a clear recipe for conflict and not a good role model.

A corollary to the communal pond was the tactic used in quite a few projects where groups were assisted to build one common pond with the idea that this would be such a positive example that each member would subsequently build one or more ponds him/herself. This too was a poor choice and has a very poor track record. Experience has now unmistakably demonstrated that facilities development should be an individual matter. If a group is the chosen entry point, then the collective work should be limited to the infrastructure (e.g., roads and canals) that benefits all members; each member building his/her own ponds or other production units.

More formal than a simple communal pond, farmer associations have also been promoted as key elements of a workable aquaculture development paradigm. Unfortunately, as with credit, there are few surviving examples of thriving organisations or societies. Inevitably, interpersonal rivalries arose and the group suffered. This approach has merit, but the mechanisms to achieve sustainable and cohesive groups remain to be verified.

Tangential to farmer associations has been the frequently used approach of "farmer leader" (a.k.a. "master" farmer) who was to be the model for use of appropriate production technologies. This mechanism had several permutations, in some of the more complex, the farmer leader was seen as a contact point for extension; it was planned that these farmers would, in turn, advise a group of farmers in their area, or other members of their association – i.e., become surrogate extensionists.

In some cases, farmer leaders were to "spread the word" altruistically; true devotees who had ample time to undertake outreach activities on top of managing their own farms. More realistic methods foresaw the need for compensation for this added effort and attempted to accommodate this need in cash and/or kind. Regardless of the structure, whether compensated or not, these activities were rarely sustainable. When compensation was offered, it was invariably linked to extra-budgetary resources and short-lived. Furthermore, if aquaculture did take off in the locale, the leader soon realised he was helping the competition and found little justification to continue.

Where farmer-to-farmer outreach systems have worked, as further explained in the following section, these have involved structures whereby the lead farmer becomes a service provider with a vested interest; by one means or another provision of technical assistance is linked to increased income for the provider. To date, this has most often happened with private hatchery operators (e.g., in Ghana, Madagascar and Uganda) whose interest is in selling seed; the better harvests obtained by their customers the more seed they can potentially sell. Similar situations would apply to individuals providing feed.

In conjunction with any collective activity in rural Africa are the subjects of gifts and associations. Projects have all too often attempted to stimulate interest in aquaculture by giving gifts: construction materials, credit, nets, seed, feed, etc. This did not work. Groups readily formed to benefit from the gifts, but once these were obtained they disbanded.

Credit, in particular has been one of the major, if unintended, gifts used by projects to encourage participation. In some cases, projects felt that credit was such an essential input that the projects themselves served as the lending agency. This was an unmitigated failure for a couple of reasons:

1. Most farmers and, indeed, local extension agents see foreign projects as givers, not receivers, of money and hence very rarely paid back their loans.

2. Farmers often resented extension agents asking for loan payments, and either avoided them or actually chased them away.

In other cases, projects provided blocks of funds to formal lending institutions for assisting aquaculturists; but un-guaranteed loans quickly depleted these resources. In those few cases where provision of credit appeared to be beneficial and sustainable, micro-financing was provided through community-based organisations such as revolving funds available to the aquaculturists in the community or group.

Credit became associated with so many failings that recent recommendations were that credit was neither necessary nor advisable for smallholder aqua-farmers; the best tactic being to avoid the subject completely.

Conclusions

Many of the promoters of aquaculture as a quick fix to the problems of food security and poverty in rural communities were, and still are, largely unaware of the history of aquaculture in Africa. These well-wishers include civic leaders, business men and NGOs who wanted to help their communities, but generally worked in isolation from either internal or external sources of quality information, in regard to both technology and approach.

Even when national aquaculture institutions were engaged, the weakness and disorganisation of these reduced their ability to provide appropriate information and other services. For example, aquaculture as a discipline had been assigned to a wide variety of administrative homes: fisheries, agriculture, animal husbandry, rural development, environment, natural resources, etc. In extreme examples, the sector was juggled between a myriad of agencies and bureaus as it sought to find a suitable home. This administrative shuffling aggravated the loss of institutional memory and made time-series data difficult to obtain.

It is true that aquaculture is a multi-faceted undertaking with many interwoven themes. It is not intuitively obvious, perhaps, where there is the best fit in terms of a bureaucratic base. Nonetheless, it would appear that political autonomy and technical uniqueness are best served when housed as a department within a fisheries ministry, or the equivalent.

It is important to remember that things that went wrong did not do so out of malfeasance or deliberate mismanagement. Aquaculture was not only an innovation, but the process of aquaculture development was also a novelty. Development started with a focus on appropriate technology. As technologies became available, it became apparent the productive use of these was a question of economic viability. Technological appropriateness was redefined in terms of economic efficiency and financial solvency. However, as potentially economically viable activities also failed to meet expectations, it was noted that the next step in the adoption process was to ensure the social compatibility of the introduced technology. Through this reiterative process, it was discovered that successful development needed to have technical, economic and social dimensions to achieve sustainability. This realisation has become a fundamental ingredient of recent aquaculture development efforts.

Finally, it is worth noting that much of what is now seen as being “wrong” was perceived as being “right” at the time it was undertaken. In this optic, in fact, many early efforts were successes in the sense that they accomplished what they set out to do – e.g., “station & motorcycle” projects built infrastructure, equipped agents and grew fish. The assumption seems to have been that state support to these activities would be on-going such that a private, independent aquaculture sector never considered. New approaches with self-sufficiency as a main goal are truly a result of a major paradigm shift.

What Went Right

It may seem as though very little has gone right. This is, however, not the case. The process through which African aquaculture has passed has itself been enlightening and those who have benefited from its lessons are more effective today than they were fifteen years ago.

Figure 8. Aquaculture has gained recognition as a worthwhile investment in Africa. Investors, however, are not looking for extensive or low technology systems. Many businesses investing in fish farming and other aquaculture systems are looking at high yield methods including complete feed, improved seed and full-time aeration (Ghana).

It is now well-accepted that aquaculture development is a multi-disciplinary process encompassing economic, environmental, ecological, social, cultural, financial, biophysical, biochemical, hydrological and other factors. The technical part of raising fish is, by comparison, easy when weighed against developing a programme that is sustainable and making significant contributions to a country’s development.

Despite the slow rate of growth, by the 1990s aquaculture had been transformed from an unknown and little-understood activity to an accepted part of most farming systems and agricultural programmes. Farmers in Africa no longer saw fish as mysterious beings that lived by eating water, but understood they were organisms to raise, very similar in their needs to chickens or pigs.

These views of aquaculture were accompanied by tangible and important technological advances in areas such as the identification of farmer-friendly spawning and rearing methods for catfish combined with a general improvement in hatchery and fish seed technology and handling.

Critical Mass

By the turn of the century, aquaculture was beginning to be seen as a business. In Madagascar, Mozambique, Angola, Côte d'Ivoire, Cameroon, Zambia, Zimbabwe, Kenya, Uganda, Nigeria, Ghana, Gabon, South Africa, Namibia, DR Congo and Tanzania, farmers were making profits raising aquatic products.

Figure 9. Some private farms represent very significant capital investment. There are cases where financing has been facilitated through third parties such as donors concentrating on economic growth – often focusing on small- and medium-enterprise development (Ghana).

In some cases, these farmers were the same individuals to whom aquaculture had been introduced through national "stations & motorcycle" programmes. Often they were initially farmers who had adopted the "self-sufficiency model". In all cases, they were farmers with an adequate resource base to be able to practice profitable aquaculture.

As the number of such farmers increased within areas of higher biophysical potential or market access, some farmers found they had passed some critical economic threshold density. As farmer density increased and demand for inputs such as feeds, fingerlings and market infrastructure became more concentrated, farmers could break out of the self-sufficiency dogma which required them to divide their resources among a variety of different, if inter-related, activities. When one farmer concentrated all his/her resources on seed production, producing reliable supplies of good-quality and cost-effective seed, other farmers no longer needed to produce their own seed but could specialise in grow-out.

Integration

While reliance on on-farm inputs had demonstrated limitations, and associated aquaculture systems were generally not appropriate for many smallholder farmers, these experiences did lead to a revamping of the principle of integrated aquaculture. In cases where farming investments were sufficiently large and sophisticated, *animal-cum-fish* feeding strategies could be economically viable. More importantly was the identification of technological and management options for integrating aquaculture with irrigation. These systems were true integrations with the intent to re-use water ("*more crop for the drop*"). Rice integrated with fish, for example, widely promoted across the region as a small-scale option with very minimal success, was found in Madagascar to be profitable at a slightly larger scale, where carp integrated with rice has since been sustainably incorporated into many farming systems and is now a very important contributor to national food security.

Extension Model

Another successful aspect of the Malagasy programme was the privatisation of government infrastructure. Early projects had subscribed to the "station & motorcycle" model, attended by the typical degradation of infrastructure and loss of investment seen elsewhere. As carp seed demand grew with the expansion of rice/fish production, government privatised former public sector facilities. Many of these were taken over by private seed producers who dramatically out-performed the previous owners.

Subsequently, privatisation of public infrastructure has become a hot topic for debate in many other African countries. While the pandemic of government station abandonment continues, and there appear to be few realistic alternatives to divestment, some governments have difficulty overcoming inertia. Although, for example, Cameroon, Ghana, Zambia, Uganda, DRC and Nigeria have agreements in principle to cede redundant public sector facilities to the private sector, these are slow in being implemented. Many installations have a political past, being in the home area of an important personage, living or dead, or being a "sink-hole" into which so much has been invested that political expediency has a difficult time letting go. Nevertheless, little by little as the choices become clearer, privatisation is continuing.

Needless to say, in some places, lessons refuse to be learned. Even as some government stations are being liquidated, in another part of the country a donor or lender is supporting the establishment of a new government station which is likely to be redundant before it is inaugurated.

Figure 10. Tilapia and catfish hatchery which has proven itself as a viable small business using locally available material and management (Uganda).

The many, repeated attempts at establishing workable aquaculture extension programmes have clearly demonstrated that aquaculture is a specialisation that is not easily diffused by generalist extension services. Providing national-level, specialised aquaculture extension services are, however, financially and logistically unrealistic.

Regardless of the extension structure, past experience has clearly demonstrated that the adoption process is relatively long. Initially, extension support should be frequent and last several years; slowly tapering off to periodic "check-ups". In addition, the Training & Visit System was not particularly well-suited to the specific needs of aquaculture and more promising results have been achieved from a structure based on research-

Box 6 Aquaculture for Local Community Development (ALCOM): ALCOM started as a Swedish-funded global programme in the late 1980s, evolving a decade later into the southern Africa regional programme on Integrated Aquatic Systems for Smallholder Farmers funded by Sweden and Belgium and ultimately based in Harare, Zimbabwe. The programme developed the "*ALCOM Model*" as a methodological link between research and development and to strengthen and mobilise national institutions and government services. This model was built on the acknowledged complexity of the small-scale aquaculture development process. By undertaking case studies which reflected the cultural, climatic, social and environmental diversity of the region, common strategies to problem solving were identified. These strategies were then adopted by other programmes in the region, quickly and cheaply multiplying the number of beneficiaries. ALCOMs objective was to promote an increase in cash income and/or animal protein in the diet of rural communities through increased production of fish from small-scale integrated aquaculture integrated or as a complement to traditional small-scale fishing. The corresponding target communities were those who depended on family scale mixed farming systems or small-scale fisheries for their livelihoods. Guidelines to enhance the role of women in inland fisheries and aquaculture were an explicit objective. The programme was innovative in taking an integrated approach to development; using participatory technologies and focusing on the social and economic aspects as much, or more than technical issues. Extension and outreach were critical elements to scale up pilot activities to national and sub-regional levels. ALCOM operated through a series of local pilot projects representing variations on a common theme (e.g., three sites in three countries developing demonstrations of sustainable integrated aquaculture and four sites in four countries demonstrating improved small-scale capture fisheries). Pilot sites were chosen to represent different development scenarios so that aggregate results reflected the true variety of technical options available. Pilot sites were overseen by a team of national project staff and seconded national officers, sometimes complemented by an international project staff member. Overall pilot operations were supervised from the programme's offices in Harare where one technical officer each was responsible for aquaculture and fisheries. The programme developed a regional information service with a library, newsletter, series of technical documents and a sub-regional GIS with integrated database. With greater human and financial resources, ALCOM was often able to have impact where governments could not. The programme became a regional catalyst and resource and was expected to culminate in its institutionalisation into the Southern African Development Community (SADC). However, this incorporation was never accomplished and the programme slowly atrophied, leaving only a strong sense of what had been lost. The enduring lesson of ALCOM was the demonstration of a technical approach and operational structure that could be successfully applied to other sub-regional or regional interventions. The programme successfully built national capacity through high quality regional backstopping. While today's priorities might well suggest an ALCOM-like programme focus on commercial and not non-commercial producers, the holistic approach remains as a positive example of potentially sustainable development – potentially because of the programme's premature end.

Box 7 Uganda Small-scale Hatcheries: One of the first efforts to establish sustainable private hatcheries or nurseries as viable small businesses was undertaken in eastern Uganda from 2002 to 2004 through the FAO's Technical Co-operation Programme. The project's motto was "Rural aquaculture development through improved access to quality fish seed – promoting farmer-friendly approaches and techniques to aquaculture through improved seed production, distribution and marketing." The starting point for the project was to answer to the question: How big must a rural aquaculture investment be to return enough money to be sustainable? Once a consensus was reached concerning a suitable level of monthly income necessary to attract serious investors, project staff set out identifying zones where a fish seed distribution business would be able to generate this level of income. Instead of following administrative boundaries, zones for investment were prioritized according to technical criteria combined with an estimate of the present and future level of fish culture activity (critical mass). Ultimately, a zone was considered as having a working radius of approximately 50 km and encompassing a sufficiently large number of fish farmers to constitute adequate economic demand to support a private seed production enterprise in each zone. Among practicing farmers, there were to be at least five "model" farmers with a minimum water surface of 500 m^2 who were willing to be trained in improved management practices. In each zone, another farmer, an "operator", was selected to specialise in seed production. A preference was given to individuals with at least five ponds and/or 1,500 m^2 of pond surface. Given the fact that fish seed distribution is at least as great a problem as seed production, operators were initially seen as managers of nurseries, buying small catfish fry from a large-scale hatchery and serving primarily as a distribution centre, making fingerlings more accessible to local buyers. As the project evolved, operators gained skills in hatchery and nursery operations for both tilapia and catfish, facilitated by expertise from Southeast Asia provided through the project. As the methodologies developed, a production cycle of 30-40 days was found suitable to raise fry to sellable fingerling size. As operators managed multiple cycles, survival for catfish increased from 2 to 47 percent, while for tilapia the corresponding increase was from 54 to 90 percent. It was also determined that an operator should sell at least 1,600 tilapia fingerlings and 1,100 catfish per production cycle to reach profit levels. It was initially thought that, as in Madagascar (Box 9), operators would also serve as extensions since they had a vested interest in the expansion of the sub-sector. However, the realities of the situation were such that the operators rarely visited other farms and, although they may be a source of technical information, they are not effective mobile extensionists. The project successfully called attention to the different options of seed delivery: few central large-scale hatcheries with satellite nurseries Vs numerous smaller-scale local hatcheries. Other issues coming out of the project include questions of quality control of seed, need for seed certification and licensing of growers, matters involving the control of brood fish quality, the need for input distribution networks and the persistent problem of providing quality aquaculture extension support.

extension partnerships and joint extension teams. In some areas, Farmer Field Schools have proven useful in moving knowledge from researchers to farmers while also providing complementary mechanisms to provide support services to aquaculturists.

Sharing Knowledge

Local successes not withstanding, a widely applicable model for sustainable and cost effective extension is yet to be demonstrated. It appears likely; however, that some kind of highly focused and qualified service aimed at clusters of producers in high potential zones appears would be more effective than some previously tried methods.

Figure 11. The growing commercial approach to aquaculture in Africa has led to investment in modern infrastructure. However, the region's comparative advantages often lie in terms of relatively cheap land and labour. Production increases in many cases may best be achieved by expansion rather than intensification through expensive facilities (Angola).

While the keys to success for aquaculture associations remain elusive, there is general and widespread agreement that producers must band together. In general, successful farmers tend to be individualistic and it is clear from past experience that any such group must find value added in working.

In some cases, the political lobbying potential of the group has motivated aquaculturists and they have found the most expeditious means being to incorporate aquaculture into the array of agricultural activities covered by the national farmers' union which then becomes their spokesperson. In other cases, farmers have joined forces at the village level to secure information exchange; a farmer representative attending "outside" training sessions and then returning to share the message with fellow village members.

The value placed on information is another demonstration of positive change over recent years. Before the "information age" many practitioners worked in semi-seclusion, unaware of the volume of relevant information available and having few prospects of being able to access this source of data. If someone wanted to gain knowledge, re-inventing the wheel was often the only option.

Today, the information revolution has struck and, although still well below global standards, Africa is progressively entering the new age of rapid electronic communications and greatly increased access to information. Researchers, educators, producers and other stakeholders now no longer have to derive their own data but can benefit from a vast storehouse of information, fine-tuning this to meet their specific needs.

From the point of view of the development process, catfish might actually be a better candidate for start-up aquaculture than tilapia. With existing technology, catfish hatchery and nursery operations foster a level of

Box 8 Nigeria Commercial Farms: In the 1970s, the government of what was then known as Midwest State sponsored one of the first large commercial fish farms in Nigeria: Aviara Fish Farm. When it stopped operations in 1982 it had 56 ha in carp and tilapia production, with harvests averaging 2,000 kg/ha and expansion underway for an additional 100 ha of ponds. The farm suffered from the chronic constraint of feed unavailability despite contracts with three local suppliers. Interestingly, the farm's major crop was carp, but it had never done any market analysis to estimate the demand for this product. Initial problems with fingering production overshadowed other concerns and it was only after the farm was under production that concerns were expressed as to how to market the crop. In the two decades since Aviara closed, the aquaculture industry in Nigeria has blossomed. There are now more than 100 commercial farms, at least two large-scale hatcheries producing more than a half a million fry a month and several local feed mills and distributors of imported fish feed. Today's aquaculture industry is based on catfish and is truly market-driven. When investors realised the opportunities for supplying highly-prized catfish to a massive domestic market, in spite of negligible public sector support, they made the commitment to "go it alone" and develop the industry. Pioneer producers had to do it all themselves: seed, feed, training and marketing. These early investors were obliged to fully integrate their operations and become self-sufficient, stand-alone firms. This individualistic, self-reliant approach was necessary for the industry to take root. Today, Nigeria's fish farmers have crossed the threshold and have both an economic and political critical mass. It is now time to specialise. It is time to adjust and for some to take responsibility for quality seed production and distribution while others devote their facilities and resources to producing table fish. This shift to inter-dependence comes at a rather high psychological cost for independent producers who have previously learned hard lessons about relying on external inputs or services. Nevertheless, it is necessary and must take place if the industry is to continue to grow. The Nigerian experience has broadened the horizons in terms of how and where to raise fish. Contrary to programmes in most other countries, much of the commercial production does not take place in ponds but in small-, medium, and large-size concrete tanks and even recirculating systems with sophisticated bio-filtration. To a large extent, the considerable investment needed for these systems has been facilitated by the high profit levels which are in turn driven by the high market price of catfish. Rapidly expanding aquaculture, however, will ultimately have a significant effect on supply and prices should fall. In anticipation, producers are exploring other options including a diversification to tilapia, at a significantly lower market value, as well as niche marketing for such things as portion-size products for the growing fast food industry. With all its dynamism, the Nigerian industry remains confronted by time-honoured constraints. The best quality feed is imported and expensive – almost prohibitively so. Producers are attempting to develop local suppliers but variable quality still favours the imported products. The private sector is also still functioning at a tangent to public sector programmes with little government technical support (extension) or monitoring. Recent supporters from segments of the public and private sectors have proposed the elaboration of a national aquaculture development strategy to address the nearly disparate tracts embarked upon by government and farmers as well as to harmonise activities across the complex federal structure of the state.

Box 9 Madagascar Rice/Fish: Rice/fish culture has been introduced into many African countries since the early 1970s. However, the sole spot where it has been adopted on a large scale is in Madagascar, a major rice producing and consuming nation. Rice/fish culture is now the dominant aquaculture system in the central highlands where many farmers routinely stock carp, or sometimes tilapia, into their rice crop. Madagascar's aquaculture history was not too different from other countries in the region and it had its share of redundant public infrastructure and dysfunctional services. In the 1990s, within the context of a joint UNDP/FAO development project, Madagascar undertook the privatisation of its government stations; ceding or leasing these to private farmers or farmer associations. The operators of these stations became PPAs: *Producteur privé d'alevins* (private fingerling producers). With cold, dry winters, the carp spawning season corresponds well with the time of planting rice seedlings in paddies. During this season, the PPAs are in full swing, sometimes bringing carp brood stock from tanks near their homes (as a safeguard against theft) to small earthen ponds where they are spawned and fingerlings nursed. PPAs were conceived as being extensionists as well as seed suppliers, acknowledging government's inability to provide direct support to the country's thousands of fish farmers. The assumption was that the more seed the PPAs sold, the more profit they made. Hence, the better they promoted good aquaculture practices, the better farmers' yields and the more seed they would buy. The logic seemed sound but the realities were different. As in Uganda (Box 7), PPAs rarely left their hatcheries where they were fully involved in the short spawning season. Even though not visiting farmers, PPAs do provide technical advice to their customers when they pick up their seed. They are also government's acknowledged local focal point and keep records as to how much seed has been provided to growers; these records forming the basis for the government's aquaculture reporting procedures. A decade after divestment, the PPAs and their hatcheries are generally doing a good job in support of the sub-sector. During this period, however, they have lost their monopoly and must compete openly amongst each other as well as amongst seeming charlatans who catch any sort of wild fish and try to sell these as fingerlings. The Madagascar industry is now experiencing a new challenge: suspected in-breeding of domestic stocks has reduced carp growth rate and farmers are considering a shift to tilapia.

assiduous husbandry that may not be frequent in tilapia growers. Once mastered, catfish hatchery systems can be easily transferred to tilapia. In contrast, a small-scale tilapia hatchery would have trouble with any other species.

Production Systems

In part due to this improved availability of information, recent years have also witnessed a notable diversification of culture technology. Cages, tanks and raceways are now becoming more common as investors learn more about available aquaculture opportunities and, most importantly, as fish prices increase due to over-exploitation of declining capture fisheries, investors see greater opportunities for profit.

Many of these new culture practices focus on improved results from the established species, tilapia and catfish, as opposed to continuing the hunt for the elusive perfect culture animal. It is also of interest to note that the earlier choice of tilapia as the best indigenous species due to ease of culture

> *Box 10 Lake Harvest*: Lake Harvest (Pvt) Ltd., established in 1997, is the single largest aqua-business currently operating in the region. This cage "farm" is located in the Zimbabwean waters of Lake Kariba. The farm consists of a 10 ha pond-based hatchery unit which supplies seed to six cage sites, each with 14 cages and capable of producing 800 t/yr. Tilapia (*Oreochromis niloticus*) are grown to 750 g and processed in an EU-standard plant with a capacity of 15 tons of whole fish a day. The main market is in Europe, but local and sub-regional consumers are also targeted. The firm's operations are impressive and have stimulated considerable regional interest in aquaculture in general and in cage culture in particular. The firm is now planning on expanding to other countries, most notably Uganda. Lake Harvest is a pace setter and a real African model for industrial-scale aquaculture. Enterprises of this magnitude can unquestionably be players in the global market as well as important stimulators of the local economy where they engage a wide variety of goods and services. Enterprises of this magnitude also require major investment. Nevertheless, Lake Harvest is a model which can be scaled down and which has demonstrated the economic viability of large-scale aqua-business in Africa. The firm has been confronted with the main constraints that befall producers of all scales; difficulties in obtaining good quality inputs and in keeping market share in the face of aggressive global competition. With a daily demand for tons of high quality feed, reliable supplies of acceptable quality feed have been a continuous challenge and a persistent risk. Equally important to the bottom line is the performance of the fish being raised. To date, African producers have not had access to better performing strains raised by industries situated in other regions of the world (e.g., GIFT tilapia). With reports that improved strains will grow twice as fast, there is strong motivation to lobby for the immediate access to such faster growing animals.

was perhaps a miscalculation. In hindsight, tilapia is actually quite a complicated culture subject, not only due to its precocious reproduction but also due to its environmental requirements for good growth. These impediments can now be partially addressed through the use of sex-reversed seed and may be further improved as better performing strains are selected.

However, most fish farmers, even unsuccessful ones, know about tilapia and know they spawn in ponds. Less wealthy farmers, in particular, are thus reluctant to pay for the better quality seed available from private suppliers, because they know they can get them free from their own ponds, even if the quality is lower.

Conversely, farmers also now know that catfish generally do not spawn in ponds. They are, thus, more amenable to purchasing catfish seed which, when grown under suitable conditions, will actually produce larger sized individuals than tilapia.

In general, it is best to use available culture species during the inception of a project; concentrating on improved management to improve growth rates. As happened in Madagascar (Box 9), inbreeding of domestic stocks might reduce growth, but, unlike with alien species such as the carp, new brooders of local species can always be collected from the wild.

Figure 12. Cage culture has been promoted in different areas for thirty years. While there were some early success stories from the lagoons of Côte d'Ivoire where an international petroleum company funded a cage operation, most of the initial attempts failed either due to poor cage design or to unprofitable management procedures. With the entry of Lake Harvest (Box 10) into the arena, cage culture has gained prominence and is now an accepted, if under-used culture system. Ghana has a producing cage farm (photo) with new entries planned. Medium- to large scale operations are also underway in Uganda and Malawi with smaller operations in Angola, Kenya and Madagascar (to name a few).

Cutting across production systems, is the pivotal question of good management. Field results have repeatedly demonstrated that good management, using the locally available genetic material, can lead to up to a 400 per cent increase in yield. If improved stocks are available, yield can again be doubled or tripled.

Good management, depending upon the production system, often required investment, bringing up the subject of credit. By and large, farmers did not have easy access to credit. Although small- and medium-scale commercial producers realistically required capital to purchase quality inputs as these became available, sources of financing were few and far between. Fortunately, in recent years considerable progress has been made in community-level micro-financing arrangements. Farmers are beginning to have access to modest sums through rural banks, NGOs or other user-friendly community-level mechanisms. Concurrently, the availability of more substantial financing through the formal lending and banking systems is becoming more accessible as lenders view aquaculture with less trepidation and a better understanding of how it can function as a profitable business.

As a business approach becomes a more common course of action, the importance of the market becomes increasingly obvious. Few producers now take it for granted they will automatically be able to sell their crop for a profit. There is renewed awareness of the need to respond to market forces, providing products that optimise profit. In general, growing the smallest marketable product tends to be the most profitable and some growers are actively assessing how this can be applied to fit consumers' needs.

Markets themselves are also changing, and are no longer exclusively local. Regional, often large urban, markets are badly under-supplied and often rely on poor-quality imported frozen products. Many export-oriented producers tend to look far a field for new opportunities in Europe or the US which, although more tightly controlled, are more transparent and ultimately perceived as more accessible than African markets where transactions are clouded by a variety of unfamiliar and frequently changing edicts. Nonetheless, as production expands, intra-African markets will be increasingly served by local aquaculturists.

Figure 13. It may be difficult to imagine how static-water concrete tanks can be profitable production systems. However, tanks of this sort are numerous in Nigeria, raising high densities of catfish with minimal water exchange and using relatively mediocre feeds.

Conclusions

Over-arching all of the above observations is the wisdom gained in terms of how to, and how not to promote aquaculture development. Across the region, there are thousands of poorly built and/or poorly-sited. When people are motivated, they can indeed accomplish amazing tasks – including moving huge volumes of earth to build levees of ponds that will never produce fish. Over-expectation on the part of these eager beavers was a major component of many aquaculture failures. With an incomplete understanding of the real requirements for, and potential contribution from aquaculture, many people extolled the virtues of becoming an aquaculturist without comprehending what this activity entailed.

In the Third Millennium, the picture is much clearer. Past failures have sensitised most as to the realities of raising aquatic products for sale. Those who enter the field today should do so with their eyes and minds open. In general, the lessons learned can be summarized as follows:

- ✓ Aquaculture is not a cure-all. It has real costs and benefits which must be systematically weighed before undertaking the activity.

- ✓ There are a variety of aquaculture systems and it is necessary to find the right fit between system and environment; undertaking prerequisite analyses before starting site development.

- ✓ Profitable and sustainable aquaculture systems most often do not produce cheap food.

- ✓ A focus on private sector development will provide complementary benefits to the public sector.

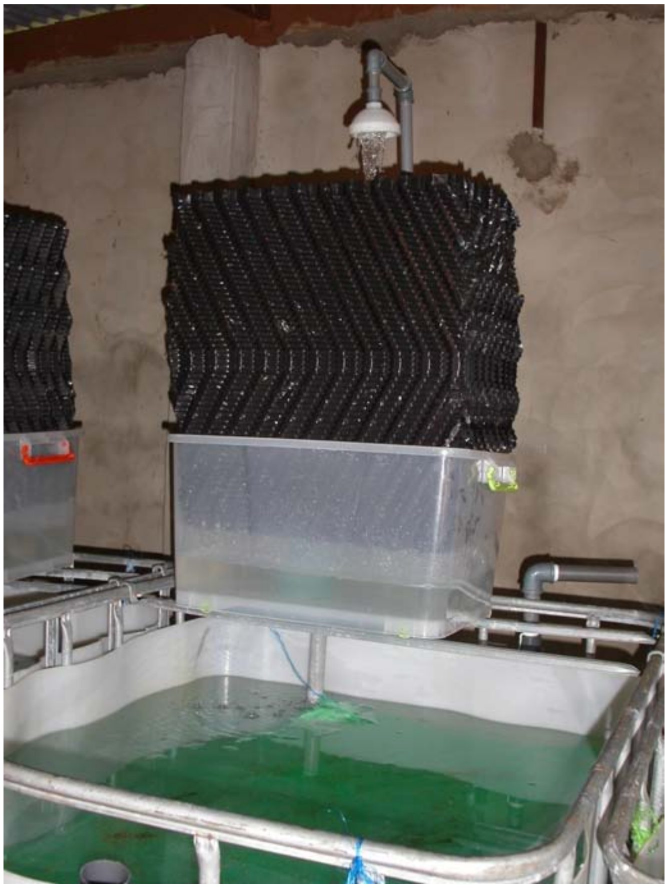

Figure 14. One of the keys to successful private hatcheries is the innovative use of locally available materials. Vats used for shipment of industrial chemicals can be used as fry nursing tanks with homemade bio-filtration and imported media (Nigeria).

- ✓ Aquaculture development is multi-disciplinary.
- ✓ Sustainable aquaculture must be economically viable, socially acceptable and environmentally benign.
- ✓ There is a growing quantity of erroneous or incomplete information available about how to do aquaculture.
- ✓ Good management, of both fishponds and the business aspects, is essential for sustainable and profitable aquaculture.
- ✓ Producing the smallest product acceptable to the market will generally be the most profitable.
- ✓ Seed distribution is just as much a challenge as seed production. A few centralised (large-scale) hatcheries producing large quantities of good quality fry which are, in turn, purchased and grown by satellite nurseries before being sold to the final grower, may be the best option for seed distribution under many circumstances.
- ✓ Stocking the smallest/youngest seed (particularly for tilapias) is frequently the best tactic for non-commercial producers. Conversely, commercial operators can shorten their production cycles by stocking more advanced juveniles.
- ✓ Small- and medium scale commercial producers will be the “motors” of aquaculture development.
- ✓ Credit is an important asset for commercial producers of all scales of operation.
- ✓ Where land and water are relatively inexpensive, further increases are often best achieved by expansion and not intensification.

- ✓ Markets are critical and need to be carefully analysed before undertaking investment.

- ✓ Aquaculture development based on on-farm inputs will make relatively modest contributions to sectoral growth. While these systems may appeal to some growers, significant aquaculture production will require the availability of aqua-feeds; either supplemental or complete.

- ✓ Aquaculture is a density-dependant enterprise. Public sector support of widely dispersed stakeholders is very expensive. A consolidation of effort is necessary to be able to focus on sites where there is acceptable return on investment.

- ✓ Aquaculture development should be private-sector-driven with the accompanying divestment of redundant government infrastructure.

- ✓ Input supply and delivery should be a private sector responsibility.

- ✓ Neither agricultural generalists nor thinly spread aquaculture specialists can offer sustainable, cost-effective and technically efficacious aquaculture extension. Extension and other public sector services must be concentrated in areas of high potential where there are opportunities to establish economically viable clusters of production.

- ✓ Given the realities of providing reliable logistic support to outreach services, it appears sustainability is highest for a relatively small number of highly trained extension teams making quarterly or bi-annual, etc. visits.

- ✓ A large part of the responsibility for information delivery must be given to producers themselves. This is best facilitated through producer groups. These groups should correspond to the aforementioned clusters, generally affiliated with input supply or suppliers. Their initial organisational structure should be based more on expediting input delivery and marketing and less on hierarchical design and bureaucracy.

Figure 15. Brine shrimp rearing can be expensive but is a worthy investment when the prices for high quality seed are high and there is consumer confidence that quality is maintained (Nigeria).

- ✓ While producer self-sufficiency may be important at some stages of development, as programmes mature and establish centres of economically viable production, producers should specialise and become inter-dependant.

✓ Communal or collective site development and the giving of gifts should be strongly discouraged.

✓ Non-commercial aquaculture systems are most often by definition integrated into the whole farming system with a recycling of nutrients. However, specific associations (*fish-cum-chicken*, *fish-cum-duck*, *fish-cum-pig*, etc.) are likely to be profitable only under particular circumstances.

Figure 16. Indoor systems can be very capital intensive, based on imported materials. These systems can also, however, be quite simple and use locally available materials as seen in the case of this farm near Port Harcourt which uses a borehole and small portable gasoline pump as its water supply (Nigeria).

✓ Aquaculture integrated into irrigation systems has under-used potential.

✓ Effective national co-ordination of the sub-sector is necessary. This requires concerted and harmonised efforts guided by clear national strategies.

✓ Tax-exemptions on production inputs or other forms of modest subsidies can stimulate commercial production.

✓ Start-up production systems should use the best locally available culture stocks.

✓ Improved stock will improve yield and these should be developed on a regional basis, with consideration given to the use of available improved species pending the development of regional strains.

✓ Introductions and translocations of aquatic organisms need to be effectively monitored and controlled.

OPPORTUNITIES IN THE THIRD MILLENNIUM

Having seemingly floundered for decades, it seems as though African aquaculture is finally on sound footing; ready, willing and able to advance and be counted among the important food producing enterprises in many African countries. This genesis is attributable to several factors. Learning from the previously cited lessons was a corner stone that positively applied years of experience to new endeavours. There were also other major contributors.

This Century has witnessed a renewed political will to develop the aquaculture. In part, this has been a political necessity as increases from country's capture fisheries needed to keep pace with growing populations became increasingly difficult to achieve. But this is also due to the fact that there are now operational and sustainable examples of productive aquaculture firms in the region. Through improved communications and increased mobility, these success stories are receiving wide coverage and politicians everywhere want to get in on a good thing.

The "good thing" is also a result of service providers (including government), investors and producers willing to undertake new approaches. These new methods include new production systems previously untried or unproven in Africa (e.g., cages, tanks, etc.). The new methods also include new ways of approaching the problem; taking a business approach to aquaculture and fostering private-sector-led development. The public/private seesaw has established a new equilibrium with a much stronger voice from, and role for, the private investor.

Figure 17. Growth of aquaculture requires capacity building along with (private) facilities development. Many investors do not want to apply extensive and/or out-dated technologies when turn-key state-of-the-art farms are available (Angola).

Increased prices have been the specific stimulus for the recent surge in aquaculture investment. This has, in turn, promoted investor confidence which has had a positive impact on credit availability.

Credit is slowly becoming more available as lending institutions gain more knowledge about aquaculture and are less adverse at according funds to the sector's development. However, progress is slow and credit is still available on a relatively limited basis and at high interest rates.

Another key element in the growth of the sector and assisting in the rational promotion of aquaculture is the growing information capacity within the region. Although Africa is still not on the cutting edge, intra-regional communications and information exchange have improved immensely.

Improved access to information has also improved publicity for aquaculture, although this has both pros and cons. Word is getting out and successes are gaining visibility. This publicity campaign is further assisted by such structures as NEPAD and the Fish for All Summit held in 2005, which strongly endorsed aquaculture. Improved visibility has also made aquaculture the subject of numerous interventions championed by the NGO community. These extra-governmental organisations can help bolster sluggish public agencies and institutions. On the other hand, they require co-ordination and can easily be misled by false claims, if they do not have well qualified technical staff.

Figure 18. Capacity development goes hand in hand with the adage "necessity is the mother of invention". Nigerian fish farmers who overcame inertia and built viable fish farms had to assume full responsibility for all activities from seed production to marketing. Here the owner/operator of a small family tank unit demonstrates how he produced his own seed in a three-by-five shed that served as his hatchery. Now the industry has grown and service providers are actively engaged in the market; growers can and should concentrate on producing table fish, buying high quality seed from industrial hatcheries.

Government institutions themselves are still suffering the aftershocks of major economic traumas of recent years. Nevertheless, while there has been a noticeable loss of institutional memory, the new staff are often better educated and even better motivated than their predecessors; not having been spoilt by the "golden years" when extra-budgetary funds permitted a varying degrees of lavishness. With effective technical support, and within the context of the new approaches to development mentioned above, the future of these agencies to oversee the development of the sector is promising.

The Need For National Strategies

Strategies (*cf.* page 13) serve as roadmaps that guide the sector, helping stakeholders achieve their designated objectives within the limitations of available resources. While essential, they are often lacking, neglected in favour of policies and plans. Accepted methods were to establish policies as more specific aims, akin to strategic objectives in current thinking. These were then supported by a "*master plan*", which was more of a review of the sector in question, accompanied by a series of annexes which constituted a wish-list of donor-supported projects necessary to achieve specified objectives.

Figure 19. Good harvests of high quality crops are feasible today if stakeholders plan carefully and take a business approach to fish farming (Nigeria).

In the three-step process we propose for African aquaculture (policies ➡ strategies ➡ plans), policy objectives are broad and only quantified in general terms (the "what" part of the process). Targets of specific plans, however, are precise in terms of quantity, quality and time (the "when, where and how much"). Targets contribute to objectives. Strategies are often not quantified but qualified. They assign roles and responsibilities (the "how"), serving as the conduits through which the plans operate to achieve broad policy objectives.

While many references define strategies and plans as being nearly synonymous, the present connotation of "strategy" is similar to the behavioural definition: a complex of adaptations serving an important function. In comparison, Webster defines a plan as: "a method for achieving an end".

The policy broadly defines (*cf.* page 13) relative achievements with non-specific designations. The plan details each explicit achievement in terms of quantifiable outputs and inputs – magnitude of the product as well as time and other inputs required for it to be produced. The strategy describes how the sub-sector and its combined stakeholders will perform and interact to promote the smooth and successful implementation of the plan. Strategies define resources necessary for plans to meet their targets.

While policy objectives tend to be universal in their function, and plan targets may seem obvious, ways and means of achieving these are far less straightforward; particularly if considered within the range of resources available in most African countries. Within the prevailing context of limited human and financial resources, successful implementation can most often only be accomplished through partnerships and pooling of assets.

The strategy helps answer the difficult question of how to obtain needed results with limited resources. As the question is difficult, it has long been avoided and many countries do not have specific strategies for the development of their aquaculture sector. With the growth of the sector at a critical stage, these questions should now be addressed and the best means is probably through the development of strategies.

As a final note, in different contexts some observers have referred to national aquaculture strategies or national aquaculture strategic frameworks. From a practical standpoint, these two descriptions can be considered as synonymous. Although the "framework" is more synoptic, the processes, content and context are basically the same.

Box 11 NGOs: Non Governmental Organisations (NGOs) have become very popular development tools in recent years. To many, they are equated with cheap ways of delivering services. In various African countries NGOs have assumed important roles in aquaculture development. In some cases NGOs are the nuclei at community level that stimulate interest in aquaculture; whether or not they have the technical capacity to support this activity if adopted. In other cases, NGOs are actively sought as surrogate extension providers as government agencies become less and less able to meet producers' needs. It is probably true that the NGOs themselves have the best intentions, but they often seem to validate the concern that a little knowledge can be dangerous. NGOs, with the best intentions, design local aquaculture interventions in complete absence of any government inputs and not infrequently in contradiction to the direction governments have chosen for the sector's growth. In extreme cases, they have introduced exotic culture species with no approval from the relevant authorities and no concerns for the long-term implications. This is not to imply that NGOs do not have and should not have important roles to play in the future development of the sub-sector. By their mandate and function, NGOs can contribute significantly to the development of aquaculture, but their inputs should be screened for quality control, co-ordinated and harmonised by some form of central government structure.

Priority Setting

There are two main objectives that are commonly promoted for aquaculture: food security and economic growth. Contrary to popular belief, these are somewhat mutually exclusive. The first thing one needs to do in establishing the strategy is to clarify which one is the priority.

Despite the predilections of politicians who tend to think first about the prices of food in urban markets, food security in Africa is largely a rural affair. An average of 80 per cent of Africans still lives in the countryside and many of these face seasonal food shortages. Policies that maintain low food prices for the benefit of the minority of Africans living in cities are generally counterproductive, discouraging production and exacerbating overall food insecurity.

In addition to being mostly artisanal farmers, the rural, food-insecure population is also the poorest segment of society. These people are not in a position to pay for either food or the extension support services necessary for them to produce their own food. Many development interventions have been devised to help these people, and many have achieved short-term success, but few have achieved sustainability. Once the subsidies are withdrawn, the project collapses.

Unless governments are able to consider long-term subsidies in terms of direct food hand-outs, or subsidized extension services, neither of which is affordable for cash-strapped African governments, many rural Africans will remain food insecure.

Sustainably putting more cash in the hands of the rural poor so they can buy food will require economic growth, the second major objective of aquaculture. However, artisanal food production systems of the type tested repeatedly over the years and described above under the section: "what went wrong" have failed to produce any significant growth. This is because most projects have relied on local (village) markets, most of which are cash-poor and rely largely on barter. With no significant cash-flow being generated by the farm, there is no money to reinvest, bank or spend to create economic activity.

In the capitalist system under which most people live, economic growth depends upon the establishment of viable businesses. However, the constraints to business in rural Africa are substantial: poor infrastructure, unskilled labour, high transport and input costs and low access to technical expertise. Calculating the minimum investment size at which a business can be profitable is a common practice and shows that in most cases, very small-scale businesses cannot make money in rural areas.

Depending upon the capacity of local government and the willingness of donors to provide money to support rural business initiatives, one could imagine a range of strategies to help them grow. The minimum, and probably the only level of support that rural investors might reasonably expect in the short term, is the provision of technical assistance. However, the level of training and extension methods employed by the existing support services is inappropriate to this type of investment. Most of the aquaculture training programmes and extension systems are funded by external donors who want to reach the lower ranks of society and have thus favoured technologies than can be easily scaled down or simplified for poor users. The opposite is what is needed for commercial investors. Extension agents should be trained in technologies that can be adapted to the calculated minimum profitable investment and then scaled up as the business grows.

Either of the major objectives for aquaculture, food security or economic growth, can be achieved, however, to properly design a strategy, one needs to be sure which objective is being targeted. For food security to be realized directly, one needs to concentrate effort on the rural poor, preferably by subsidizing extension, especially marketing, support. This has to be viewed as a long-term investment, but could well be worthwhile, if affordable.

If one wants to target economic growth, one needs to find means of supporting the growth of rural businesses that are of a sufficient scale to produce adequate profits. This will probably mean abandoning the poorest of the poor as a direct beneficiary of extension services. Providing direct technical assistance to investors who want to build fish farms in rural areas as a money-making venture, which can then serve as an engine for general economic growth and rural employment, would probably be the cheapest and quickest way out of poverty.

Strategic Approaches

Regardless of which main objective is sought, aquaculture is a multifaceted enterprise and encouraging its development requires a broad-based and holistic strategy encompassing many technical aspects and the interests of many stakeholders. The following sections discuss essential components to consider in the elaboration of any national strategic plan for aquaculture:

Figure 20. Seed is arguably the linchpin for expanded national aquaculture growth. Seed production technology is, to a large extent, known and distribution can be addressed via various means. Viable seed supply business must be established if the sub-sector is to expand and these firms require a critical mass of customers if they are to make a profit (Angola).

Seed

Seed has been long acknowledged as one of the pivotal issues in aquaculture development; specifically the lack of good quality, affordable seed. Seed is also the technical entry point where most aquaculture technicians can have the greatest immediate impact; reliable availability of better quality seed providing rapid improvements to mediocre harvests, increasing the number of cycles per year and lowering costs of production.

A clear lesson from past projects is that seed production is the domain of the private sector. Closely aligned to this message is the fact that seed distribution is as much, or more, of a challenge as seed production.

For producers interested in maximizing profit (i.e., commercial farmers), seed should be seen as a commercially produced, purchased input, and not something collected from the bottom of the pond at harvest. Most commercial aquaculture producers will find that the rather complicated process of on-farm seed production is not the best use of available resources and that, seed is best obtained from dedicated hatcheries and nurseries where seed production and delivery is the core business.

Under the overall umbrella of a private sector initiative, there are many options for seed delivery. A single hatchery may produce the "stocker-size" animal or several operators may rear different stages between fry and juvenile. The decision as to which method fits the given circumstances is one of economics: how can a reasonably priced, quality product reach the grower?

Private, commercial seed supply implies the adoption of tried and true technologies. This, in turn, implies the use of species for the reproduction of which there is an adequate knowledge base; experimental reproduction of new species should remain the domain of the researcher until the technologies are sufficiently well established to attract investors. In some cases, wild-caught seed may still be an option as long as biodiversity and environmental conservation are not adversely affected.

Seed quality, particularly in terms of known age of stocking material and uniform size, can be improved significantly even with existing genetic material. Nevertheless, as producers improve their management practices to the point where inter-strain differences in performance are made manifest, they will demand improved strains. Strategies need to foresee this inevitability and allocate responsibilities for the development and maintenance of a breeding programme. As fish breeding continues to be experimental, some kind of research involvement is needed and might best be sought through a private-public partnership, with public institutions and infrastructure playing leading initial roles and the private sector taking the results directly and applying them on-farm.

Buying fingerlings represents a substantial investment and obliges farmers who want to make money to invest proportionally in other inputs so as to justify and recuperate the cost of the fingerlings. Being thus obliged to rely on a private seed supplier, hatcheries and growers will naturally evolve into a network relationship. This will contribute directly to the establishment of operational clusters of farmers needed to create the critical mass necessary for efficient delivery of support services.

Figure 21. Locally available, good quality and affordable fish feed is a critical factor if aquaculture is to expand and contribute significantly to economic growth (Nigeria).

Feed

As with seed, all scales of commercial producer should see feed as a purchased input, rather than something one finds lying about on the farm. Unlike with seed, however, feed quality, prices and availability are less under the control of the producer and the aquaculture technician. Animal feeds rely on agricultural products and should not compete to the detriment of lower-income humans for the use of these inputs. Nevertheless, off-farm feed inputs are necessary if harvests are to improve.

There are two main options for feed supply: purchase ingredients and prepare feeds on-farm or purchase prepared feeds from commercial mills, be they micro or large businesses. In both cases, the feed may be supplemental or complete. Aqua- feeds are most effective when pelleted and pellet quality (especially water stability) will be an important factor.

Transport and delivery of feeds and/or feedstuffs will also be critical in determining profitability and minimum investment size, and may well be facilitated through localised distribution nodes similar to the seed supply centre, further reinforcing network cohesion and inter-dependence.

Credit

The 1999 Africa Regional Aquaculture Review (CIFA/OP24, FAO-RAF 2000 – Executive Summary appended) concluded that most non-commercial farms hoping to achieve food security objectives are not constrained by lack of credit. While this may remain the case, commercial farmers seeking economic growth objectives do need capital to purchase inputs of feeds, seed, equipment and infrastructure in sufficient amounts to meet minimum investment targets. Crop insurance has also been mentioned as a possible contributor to investment security.

Strategically, many small and medium scale commercial investments will produce more overall economic growth than a few big farms. However, in most developing countries large (industrial) producers find it much easier to obtain credit than small- and medium-scale commercial operators. For this group, the capital requirements can be modest and correspond well to a variety of community-level micro-credit mechanisms.

Marketing

The fact that a product might be scarce in the market does not mean that anyone who produces that product will find it easy to sell. This is especially true for aquaculture products which are frequently more expensive than, albeit often of lower quality than products coming from capture fisheries. Accordingly, the market is a very important element of any strategy; but one that is often neglected or completely forgotten. To be profitable in the long term, aquaculture investments must be market-driven and the aquaculture sector overall must be investor (private enterprise) driven.

Global markets are a reality as numerous African aqua-producers target North American and European consumers. Concurrently major national and sub-regional African markets remain under-supplied with countries spending millions in hard currency for the importation of fishery products.

Strategically, marketing issues should not be limited to the sales and distribution of aqua-products, but also the marketing of production inputs such as feed, seed, equipment, etc.

Information

Information includes extension, outreach and non-formal education. There are two essential dimensions to this key element; information quality and information delivery. Much of the developmental information generated is "explicit" in nature. Explicit information is derived from the scientific process of observation and analysis and then transcribed into a format for diffusion. This progression takes considerable time, with a substantial lag before the information is available to the consumer. As a consequence, explicit information is used extensively by students and educators but tends to be enough behind-the-times not to be particularly useful to decision makers and others on the cutting edge. Deciders of the public and private sectors, require "implicit" information which is in effect un-coalesced knowledge and expertise that is articulated on-the-spot to address a specific issue at a specific time. Thus, while implicit information is the more indispensable for development and investment decisions, the spontaneity required makes it difficult to make available vis-à-vis "stored" explicit information.

Delivery of any information is seemingly equally problematic and some have considered extension and outreach as the greatest challenges confronting the development of the global agricultural sector. Preceding chapters have described various attempts aimed at establishing aquaculture extension services – most of which have failed. Strategically, information dissemination must take a polymorphic approach relying on a mixture of direct and indirect communication channels ranging from the mass media to farmer-to-farmer and agent-to-farmer personal exchanges.

Education

Education is intrinsically linked to information and few would argue that aquaculture education is needed across the full spectrum of the sector from the producer to the highest level decision maker. It should be clear by this stage that this education must be applied and applicable. Equally important is to strategically assess the economies of scale for providing education at different levels and for different target groups. Education is a question of the ability to deliver, the cost to deliver and the demand for delivery. A growing aquaculture sector will manifest high demand for education and training at the producer interface, including individuals from both private and public sectors. However, as one moves up the hierarchical ladder, fewer and fewer individuals are required and the specific costs per person higher. At these levels, economically viable numbers of trainees or students may only be found at sub-regional or regional levels. Strategically, this arguers for an intra-regional education and training network that can positively address these economies of scale.

Research

There is no doubt that research has played, and will continue to play an important strategic role in the development of aquaculture. However, it is also likely, albeit not categorical, that researchers perpetually identify research as the key to development; citing the pressing requirements for more resources to address critical research needs. Globally there is a large body of relevant technology and methodology which could and should be at the disposal of African aquaculturists; but which often is not. Thus, the essential factor is determining what exists but is inaccessible and what remains to be "discovered" through research.

Examples of fundamental unknowns that rely on research effort include, as indicated above, the reproduction and culture of heretofore unutilised species as well as the improvement of existing genetic material. At the same time, such topics as use and preparation of local nutrient inputs (feeds and fertilisers), catfish or tilapia hatchery techniques and stocking ratios, etc., while admittedly having knowledge gaps, do not represent the "burning" issues where there is the highest return on research investment in terms of production for the sub-sector.

Cross-cutting elements

Strategic approaches to aquaculture development are underpinned by some fundamental principles based on years of experience which apply to all rural development options and interventions. These cross-cutting and common elements include the concepts of critical mass, high potential areas, high potential areas and profitability.

Aquaculture cannot be practiced everywhere; it has its discrete set of prerequisites which must be respected. In spite of the enthusiasm of a would-be fish farmer, the best service one can provide this individual is to say "no" if the site does not have sufficient water, suitable soils, market access, etc. When we try to bend the rules the outcome is rarely favourable and the dissatisfaction on the part of the farmer much greater than it would have been if the pond had never been built.

Respecting the norms means, *de facto*, concentrating effort in high potential areas. These areas need not only the biophysical potential but also should meet economic capacity and social suitability criteria. Where these prerequisites converge, there is the greatest chance for success and the best opportunity for developing sound and sustainable demonstrations of successful aquaculture.

This leads to the next cross-cutting element: profit. Activities along the entire value chain need to be profitable. Concentrating on high potential sites will improve the chances of profitability but will not take the place of a comprehensive business plan.

Profit also has a density dependant function when taken in the context of a national programme. This is the concept of critical mass. Part of the marriage between systems and sites is the verification that a critical mass can be achieved and that this critical mass can be composed of profitable, hence sustainable, enterprises.

How To Implement A Strategy?

At present, strategies or strategic frameworks have been elaborated for Cameroon, Zambia, Ghana and Madagascar. A strategy development process has begun in Angola and is likely to start soon in DR Congo and Nigeria. However, no strategy has yet been implemented.

Implementation is, in the first instance, an administrative process that formalises the strategy. In some countries, this process necessitates legislation while in others it is less complicated and can be affected through official ministerial approval.

However, the strategy is not an ironclad rule but an iterative process. To a large extent, by articulating the strategy and discussing it in stakeholder fora, the elements gain visibility and varying degrees of acceptance.

In an ideal world, the strategy is elaborated in a participatory way with due attention given to the guiding principles and best practices. The resulting document, although only the first step in the process, is then formalised according to the prevailing procedures. This legitimises the strategic approach and its inherent elements.

In theory, the approved and adopted official strategy, as an iterative and flexible guide, is then overseen by a National Aquaculture Task Force composed of representatives of key stakeholder groups including the public and private sectors and civil society. The Task Force is charged with the responsibility of up-dating and revising the strategy as the sector evolves.

In the final analysis, formal approval and adoption with the subsequent monitoring by a Task Force requires government initiative. If there is adequate political will, the process could move quickly and efficiently. But governments are by nature cumbersome and often inefficient. What is to become of the strategy if it is elaborated and then lost in the void of bureaucracy?

If the strategy follows the guidelines presented in the present document, it will promote commercial aquaculture. Accordingly, in the absence of sufficient public sector political will, the private sector should have a vested interest in keeping the strategy "alive" and up to date.

In this scenario, the stewardship of the strategy could be assumed by a national aquaculture association. This should not be confused with the farmers' associations or groups operating at local or community levels to directly assist producers; expediting input availability, market access, extension support, etc. The national association should be a political lobby group open to one and all. The national association should, by default, harbour the strategy and ensure that it reflects changing producer needs and opportunities. The national association could have other ancillary functions such as producing periodic newsletters, maintaining databases of producers or linking to regional technical organisations.

Best Practices

Adoption and adherence to best practices for the protection of the environment and insurance of high quality inputs and outputs is essential for the sustainable growth of aquaculture. Many of these practices are incorporated in the FAO *Code of Conduct for Responsible Fisheries*.

Obviously, governmental adoption of codes and covenants is a long way from on-the-ground implementation. This gap between theory and practice was less important when the majority of the sector was composed of scattered, non-commercial farms. These farmers with fishponds functioned at a low enough level that it was improbable their practices would have any significant off-farm impact. Nonetheless, any stakeholder has the potential of having a negative environmental impact, particularly with regard to the introduction of exotic or controlled species as well as by the sale of sub-standard products (inputs of foodstuffs).

As the sector evolves to a more commercial orientation, best practices become increasingly important; not only for their potential deleterious impact on the overall physical operating environment but also on the political and economic environments, including influences on such critical areas as lender and consumer confidence. For sustainable profitability, it is incumbent on all stakeholders to demonstrate transparency and adherence to accepted norms.

On the production side, major areas of interest involve environmental impact. This requires sound environmental impact assessments (EIAs) prior to site development, as well as effective monitoring and control mechanisms. Specific issues include the quality and volume of discharge waters, on-farm use of chemicals and pharmaceuticals and potential introduction of alien or genetically improved organisms. With respect to the supply side, aquaculture needs to control its products; be they feed, seed or food fish (or other aqua-products). These control procedures need to be based on solid public/private partnerships.

At present, few governments have the ways and means to exercise the level of control necessary to effectively monitor the sector and its products. Licensing and certification of different segments of the value chain is one way to initiate control measures. However, qualified public sector staff will ultimately be required to verify and validate activities at farm level.

Regional Issues

There are economies of scale for aquaculture development which argue in favour of a regional approach. While capacity building at all levels is a priority for all national programmes, the requirements for human capital on a country by country basis are relatively small and it would be hard for a single country to justify a world-class aquaculture training and education institute to fulfil only national staffing needs. The same types of analyses apply to research where top-notch facilities are expensive; the costs most easily absorbed when shared among several countries.

In the 1970s, UNDP and FAO established regional aquaculture centres as part of the global Aquaculture Development and Coordination Programme (ADCP). One legacy of ADCP is the Network of Aquacultures Centres for Asia (NACA). NACA has been transformed from a regional centre within a global programme into an active Intergovernmental Organisation (IGO) supported by countries in the region (Asia) and providing high quality services to the region. The sustainable positive impact of NACA on aquaculture development in Asia has led to a call by FAO and its development partners for the establishment of a similar IGO for the Africa Region: NACAf – Network of Aquaculture Centres of Africa.

A number of institutions in Cameroon, Côte d'Ivoire, Kenya, Malawi, Nigeria, Uganda, Zambia, and South Africa have expressed interest in being part of such a network. In addition to specific aquaculture institutions, sub-regional Economic Communities (RECs: SADC, ECOWAS, CEMAC, etc.) have periodically indicated interest in assuming some form of co-ordination role for a regional or sub-regional aquaculture programme.

If implemented, NACAf would have a co-ordinating function for the region; liaising with other regional bodies and institutions, co-ordinating research and training, providing direct technical assistance, etc. NACAf could even have regional oversight duties for monitoring the implementation of national strategies as most of these will have similar templates and, in the future, rely on NACAf for varying degrees of assistance.

In the short term, NACAf could gain some institutional support from the Committee on Inland Fisheries of Africa (CIFA) which has endorsed its establishment and provides a loose intra-regional structure which could facilitate early action.

Risks

When aquaculture came to the forefront as a development tool in Africa in the 1970s, its future was so fraught with over-expectations such that it could never achieve realistic goals of improved food security and economic opportunity. In the current millennium there has been a changing of the guard and many of aquaculture's past failures have been forgotten. There is once again political and investor willingness to support aquaculture; but this support must be couched within realistic boundaries. It must be born in mind that aquaculture can contribute to market supply, economic growth and national development. But, it is not a cure-all.

While the new team of stakeholders may have forgotten many of the past pitfalls, this dwindling institutional memory also means that there has been a loss of both positive and negative experiences as well as lessons learnt. Specific snags that appear in many current national programmes include:

- *Extensive absences by key national decision-makers and technicians* – improving resource levels means that there are more study tours, more meetings and, in general, more excuses to be out of the office;

- *Instable structures* – new attention to aquaculture has prompted some to hastily establish a variety of institutional and community structures which may be found to be built on shifting sands as they are a quick response to a perceived problem which is not fully understood and/or a quick fix to enhance eligibility for external support with the prerequisite solid technical foundation ;

- *Conflicts over resources* – growing and more concentrated human populations are leading to increasingly grater competition, not only for human and financial resources, but also for essential natural resources;

- *Poor quality control* – few countries have functioning mechanisms to control the quality of aquaculture inputs or outputs, all the while such controls are more and more important in globalised markets;

- *Poor evaluation & monitoring* – as with quality control, little, if any systematic evaluation and monitoring is undertaken and the structures for doing so are often weak or nonexistent;

- *Continued pressure applied for more research* – as researchers tend to be among the more erudite and vocal of stakeholders with a vested interest for continued and even expanded research, there is, in some cases, a tendency to support research for research's sake – there are topics that require participatory and demand-driven research, but there is also a great body of information which is available and not utilised;

- *Experts* – an old maxim says an expert is some one who is 50 kilometres from home – in many ways aquaculture has had an almost paranormal aura and it has been difficult to judge who really is and is not an expert – this phenomena has been aggravated by the growing concentration on using local expertise – expertise which, in the case of aquaculture, may often be realistically lacking and inputs chosen from a proxy source for political expediency;

- *Communications* – in spite of impressive improvements in communications technology in the Region, there are still noteworthy communications inefficiencies;

- *New is better syndrome* – as aquaculture is mainstreamed, there a tendency to be attracted by reports of seemingly new, high performance tools which may or may not be appropriate to the prevailing circumstances;

- *Too many chiefs* – in some of the evolving structures appearing at various levels to "deal with" aquaculture, it seems as though there are indeed too many chiefs and not enough practical "fish handlers".

CONCLUSIONS & RECOMMENDATIONS

Decades of support to aquaculture in Africa have not been for naught. Important lessons have been learnt and aquaculture is now a known commodity throughout most of the region.

In terms of financial support, from both public and private sources, the doldrums of the 90s have led to the renaissance of the new millennium. In practical terms, this translates into renewed political will and here-to-for unseen levels of private sector investment (Appendices I & II). This political will must be used wisely and carefully converted into tangible increases in production from the sector.

An national strategy (Appendix III), supported by a wide range of stakeholders, is a necessary and positive step, even if not formally adopted or written into law. An awareness of the new paradigms is essential. New roles and responsibilities will promote growth, improve quality of products and increase accountability.

Extension, outreach and distance learning, as interrelated parts of the same processes of education and technology transfer, are critical elements for any national programme but remain outstanding problems with no easy solution (Appendix IV). Unlike many technical issues being confronted by the aquaculture sector, extension will likely not have a common solution across the region. A variety of public and private interventions will inevitably be relied upon in the short- and medium-term. In the longer-term, sustainability will likely depend upon some form of pay-as-you-go service where producers will invest in high quality external technical assistance, either from input or other service providers.

While extension may be the exception to the premise of common solutions for common problems, commonalities exist and are likely to remain for some time to come and there will continue to be a need to provide assistance to addressing these collective concerns. Some form of regional structure such as the proposed NACAf may be the most expeditious and logical mechanism to service this need.

Overall, a practical and applied approach is necessary. For the sub-sector to grow it needs people who know how to grow fish (Appendix V). This is not a time for theory and debate, but a time to make difficult decisions and take decisive action to ensure that the momentum that has developed over recent years can guide the sector forward and see Africa become a major global aquaculture producer.

WHAT NEEDS TO BE DONE?

Preceding pages have attempted to document past experiences, both positive and negative, as background for a series of lessons learnt. These lessons have, in turn, been used as the bases for strategies to support aquaculture development. These strategies are elaborated through an iterative and participatory process involving all stakeholder groups. In theory, strategies are to become formal instruments to guide the sector. Even in the absence of the formal instrument, this process for analysing the sector and deciding on what actions to take is a worthy one. Yet, there is much to be done…..

Governments

Government that have not embarked on the strategic process should do so. As the number of finalised strategic frameworks increases, newcomers will be able to benefit from these to avoid undertaking the whole process, rather simply reviewing those instruments that have been developed and picking those elements that are most suited to national conditions and priorities. With or without an approved national strategy, governments will need some form of national oversight capacity to monitor the growth of the sector.

Within their national structures, governments will need to facilitate investment. This will include such items as establishing a "*one stop shop*" for would-be investors where the entrepreneur concerned can obtain all relevant information in an easy to follow format. This facilitation should be expanded to such activities as EIAs which, though critical, need to be practical and undertaken in collaboration with the private sector, using the best available information.

Governments will need to assess carefully their options for the provision of aquaculture extension and outreach support. While no cook-book approach can be offered, there are a number of possibilities including a much greater emphasis on private sector channels.

Governments will also need to carefully assess their aquaculture-related programming with particular reference to research and education. Research tasks need to be demand driven and educational needs, for all levels, need to be in relation to the realistic needs of the sector. These two areas of public sector investment need to be scrutinised in regard to economies of scale and options for sub-regional or regional integration and/or cooperation.

Governments need to assiduously review direct and indirect financial support to the sub-sector. While "gifts" should steadfastly be avoided at all costs, there are other mechanisms to facilitate growth including reduced or no import tariffs on aquaculture materials and supplies as well as campaigns to educate lending institutions about the profitability of aquaculture.

Most importantly, governments need to understand and accept that their roles are changing. There should be no reticence to divest and reform. Government has an essential role in the future development of aquaculture, but this is a new and rapidly evolving role, more of a facilitator than a prime motivator. If government does not rapidly and whole-heartedly take up the challenge, it will run the risk of being sidelined to the ultimate detriment of the entire sector.

Industrial Producers & International Investors

Big business and big money can move mountains. When the resource base is large, action can be very quick and decisive. It can, in fact, be so quick and decisive that it overtakes the natural evolution of the sector. This steamroller effect can, in the short term, create more jobs and put more fish (or other aqua-products) on the market; but, it can also be so hasty as to border on being rash and reckless. In many cases, big business wants things done yesterday and no forward movement, be it ever so progressive, is ever fast enough.

This precipitous way of doing business has resulted in the illegal introduction and translocation of numerous alien and un-approved species. It has led to ill-advised site selection and consequent degradation, and the investment of scarce financial resources in more than a few White Elephants.

There is no question that there is a high level of interest from all segments of the private sector in investing in aquaculture. This is definitely a good thing. Nonetheless, investments and developments need to be made rationally and with due consideration to the process. Governments can facilitate, but this is only of use if investors agree to follow the prescribed procedures and adhere to the prevailing rules and regulations.

Industry must make a public commitment be responsible stakeholders and to abide by established procedures. Moreover, given the nascent stage of the industry, industry will have to assume at least some of the costs for research and development. Whether with full or partial support, industry needs to invest to be able to recover their venture capital. Better feeds, better information channels, improved seed, more applicable technology, expanded market access – these will all benefit the big producers but have spin-off affects that will benefit smaller produces and the sector as a whole.

Small- & Medium-Scale Commercial Producers

While industrial producers can rely on their own resources, small- and medium-produces still need external assistance. This assistance can come from government, producer associations and/or the international community. In the first instance, however, assistance must come from the producers themselves. The new strategic approach of concentrating in high potential zones will automatically lead to a clustering of profit-oriented producers. But these individuals must overcome their traditional and cultural aloofness and actively "bond" with other members of the cluster. They must truly buy into the principle of the power of the group and become team players.

This is not to imply that formal producer structures following Robert's Rules of Order are required. There is a whole spectrum of opportunities in terms of assembling people with common problems and aspirations. Certainly the ability to "pull down" services from government and international donors should be one of the prime motivators.

In the final analysis, small- and medium-scale operators cannot “go it alone”. They need some form of structure at the cluster level to organise their operations. They also need some broader umbrella structure to give them a political voice. As with other previously mentioned matters, here too there are economies of scale – a political voice is heard when it represents a sufficiently large group which can potentially exert political power. If this level of engagement cannot be achieved at national level, sub-regional or regional structures need to be considered.

The Non-Commercial Segment

The non-commercial segment exists and will continue to do so. This is as it should be. Non-commercial stakeholders are legitimate actors in the sector. However, by choice, their level of operations is such that it does not warrant significant public or private sector investment. They will benefit through trickle-down actions from the overall development of the aquaculture industry. Non-commercial farmers closest to clusters will benefit most while those in the most remote areas will continue to have the greatest challenges when seeking assistance or inputs.

Service Providers

One of the major actions that defines this phase of aquaculture development is the emergence of service providers. Private and public service providers are crucial for the continued positive evolution of the sector.

Seed production and distribution has been discussed in detail as an activity, which, when undertaken profitably by the private sector, can be a vital catalyst to the growth of the sector. Seed distribution centres, as hatcheries or nurseries, can also serve as the hub of a cluster. Seed distribution, in large African countries, is a challenge. In addition to hubs that are tactically well chosen, the industry needs to rely on public transport for distribution. With the ready availability of good quality plastic bags and pressurised oxygen, there is no reason that relatively large qualities of seed cannot be packaged for day-long shipment within any country.

Feed is another area where private service provision/specialisation is key. In some cases this may be distribution of imported feeds while in other cases it can involve milling and packaging of locally produced products of acceptable quality.

Private extension is also an area of growing interest. There certainly are possibilities for private extension programmes as well as for private/public partnerships. Whatever mechanism is used, the provision of appropriate and timely information will be challenging but highly valued by producers. Providers of information will be influential and must take care not to disseminate misinformation.

Private pond construction services, both mechanised and manual, exist in several countries. As the sub-sector grows there will be increasing demand for these services and a need to validate the capacity of the service providers.

Other areas which may appear in the service sector as the sub-sector and industry grow could include animal health and food quality control. For these specialities, as well as all other service provision, the state will need to keep pace with the development of specialised services, establishing standards and putting in place mechanisms for certification and quality control combined with regular reporting and periodic monitoring.

Civil Society

Civil society outside the production and service activities constitutes the target group of the sector; the customers for aquatic products. It is necessary to keep in touch with this indispensable group and to bringing them on board for pivotal decision making. The sector is accountable to civil society. Nevertheless, as the beneficiaries of the sector, civil society has a responsibility to keep itself informed about its workings. On several occasions, concerns expressed by civil society have resulted in the expenditure of great sums of money only to find out that these concerns were ill-founded. Governments need to work hand in hand with civil society, especially civil society organisations in areas of high aquaculture activity, to ensure there is a free flow of good quality information.

International Community

The international community and donors still have an important role to play. While there is growing private sector investment, growing awareness and growing political will, the sector remains vulnerable. It will take time for solid roots to develop.

Ironically, at this time of an aquaculture renaissance, most African countries are in severe economic straits. Furthermore, the doldrums of the 90s have resulted in a significant loss of experienced and tested human capacity; a loss to the combined effects of HIV-AIDS, early retrenchments and the Diaspora. In the aggregate, growing political will is confronted with the realities of greatly reduced public coffers as well as greatly reduced human capacity. Countries look to the international community to assist in filling this gap.

In regard to external support, it is probably worth mentioning the need for donors and other external supporters of African aquaculture to adopt a common and current approach. There remain cases of donors following antiquated practices and acting in isolation rather than partnerships. There are specific cases of direct support for the building of new government stations, in spite of the convincing arguments for divestment and privatisation, and of provision of a wide variety of “gifts”, although the negative impacts of such give-aways are well documented.

It is necessary for governments to help set the agenda in consultation with representatives from all national stakeholder groups. Donors and others from the international community should then see how their own priorities and resources can be merged into the national programme to the benefit of all – and not the inverse, where national programmes are moulded to meet donors' requirements.

There is a West African proverb that states: "*eni man fit sen ai fo obasia wata*". In other words, "anyone can see across a river" – achievement demands effort, while energy directed toward a goal offers a reward. African fish farmers have been looking across the river for years, seeing the opportunities on the other side but not being able to get there. There is now a chance to cross the river – do not let it slip away.

Appendix I: 1999 Africa Regional Aquaculture Review -- Executive Summary[§]:

INTRODUCTION

Twenty-four years ago FAO organized the ***First [Africa] Workshop on Aquaculture Planning*** in Accra, Ghana, with the objective of promoting aquaculture development in the Region. The Workshop elaborated recommendations which underscored, among others: the importance of having national aquaculture development plans; the need for a regional training and research centre; the necessity for suitable systems for the collection and dissemination of information; the requirement for additional training at the country level; and the need for coordination of development programmes (FAO, 1975).

In the ensuing period nearly every country in the Region[**] developed some form of aquaculture. Aquaculture seems to fit naturally within African farming systems. Yet, in spite of the Region's apparent underutilized resources of land and water, available labour and high demand for fish, aquaculture has not fulfilled its expectations and the Africa Region remains the lowest aquaculture producer in the world.

The FAO Regional Office for Africa organized the present ***Africa Regional Aquaculture Review*** to assess past aquaculture development efforts, establish a list of lessons learned and to propose a strategy for the way forward – the way to achieve enhanced aquaculture development across the Region.

The Review is based on the premise that there are common denominators affecting aquaculture development regionwide. Hence, it is possible to form a regional strategy that can serve as a template at national and local levels.

The foundation of the Review is provided by individual reports assessing aquaculture development in ten African countries: Cameroon, Central African Republic, Côte d'Ivoire, Kenya, Madagascar, Malawi, Mali, Nigeria, the United Republic of Tanzania and Zambia. The Review was organized around Working Groups, each dealing with one of four major themes of aquaculture development:

- public sector support to aquaculture development (excluding extension);
- aquaculture extension;
- small-scale integrated aquaculture systems;
- medium and large-scale aquaculture systems.

PRESENT SITUATION

For the ten countries assessed, the following elements describe the present situation for at least 80 percent of the national aquaculture programmes:

- little government support for aquaculture;
- government stations and hatcheries abandoned;
- private fish ponds abandoned;
- feed and seed shortages;
- reduced aquaculture extension activity;
- shortage of field staff;
- loss of institutional memory;
- lack of access to available aquaculture information; and
- lack of reliable aquaculture statistics.

Most countries are focusing on small-scale integrated systems producing tilapia and/or catfish (*Clarias* or *Heterobranchus*). As effective extension becomes more difficult, there is an orientation to rely

[§] Executive Summary of CIFA Occasional Paper No. 24: Africa Regional Aquaculture Review, Proceedings of a Workshop held in Accra Ghana, 22-24 September 1999

[**] FAO figures indicate some aquaculture production for every African country except Eritrea, Somalia, Western Sahara, Chad, Mauritania, Djibouti, Equatorial Guinea and Guinea Bissau (FAO/FIDI, 1999).

increasingly on farmer groups (fish farmer associations). There is also a growing interest in commercial production and greater involvement of the private sector.

The Review concluded that: (a) aquaculture is now known throughout Africa as a result of previous extension efforts and (b) adoption/acceptance, even if on a modest scale, has been noted in most countries.

LESSONS LEARNED

policies and plans

1) an aquaculture development plan should help focus development geographically and facilitate control and evaluation (monitoring) of the programme;
2) a lack of government policy and support has led to donor-driven interventions which usually cannot be sustained at the end of projects;
3) field activities should be decentralized on the basis of agro-ecological zones;
4) the frequent transfer of personnel has greatly hampered development plans and affected sustainability;
5) major government fish culture stations should be given financial autonomy and put under good management;
6) public infrastructure should ultimately be self-supporting;
7) farming inputs should not be distributed free to farmers but should have at least a subsidized price;
8) credit is not necessary and hence should not be provided to small-scale integrated farmers;
9) there has been a lack of coordination in development assistance;
10) commercial aquaculture should be promoted whenever possible;
11) farmer participation in development programmes, which has been lacking, should be encouraged;
12) access to land is an important issue that needs careful analysis;
13) marketing is also another issue that is often overlooked but can be critical to the establishment of aquaculture operations;

seed

14) centralized and subsidized fingerling production and supply is a disincentive to private sector involvement and creates shortage of seed;
15) fish seed should be produced locally, in rural units involving small-scale farmers;
16) the age of stocking material (fingerlings) must be known if good results are to be obtained;

extension

17) extension duties should not be combined with law enforcement;
18) extension efforts should be focused on small-scale model farmers operating under favourable conditions (water and soil, interest and dynamism, experience with other resources, etc.);
19) from such model farmers, the farmer to farmer extension approach should be developed through group demonstrations, field days, advice, fingerling production/sale, etc.;

research

20) on-station research to support small-scale aquaculture development should be based on inputs commonly available to small-scale farmers and it should be farmer-driven through joint activities;
21) sociocultural surveys should be conducted before introducing a new technology to a region;

aquaculture technology

22) technology should not be based on imported commodities (e.g., hormones, feeds, etc.);
23) selected culture species should be able to be reproduced by farmers themselves;
24) the integration of animal husbandry with small-scale aquaculture is often inappropriate for smallholder farmers;
25) there have been frequent pond site selection errors;
26) there has been a lack of technological flexibility; and
27) there have been inappropriate methods of technology transfer.

In addition to those items listed above, the Review made the following remarks:

(a) **Government stations**: stations often serve one or more of five common purposes: fingerling production, foodfish production, demonstration centres for extension activities, training and/or research. The first three purposes should gradually be disengaged from government. During the period of disengagement, training should be provided to private sector units such as fish farmer associations and entrepreneurs, for taking over such stations in a sustainable way. Government should maintain its support for training and research.

(b) **Regional centres of excellence**: where a centre has capacity to combine both research and training, it should carry out both functions because research activities can greatly complement training. An evaluation of existing centres should be undertaken with a view to determining their respective roles in the proposed new setting

(c) **Advisory committees**: national committees composed of both potential and existing stakeholders should be established to guide aquaculture development. These could be decision-makers, policy-makers, academics (socio-economists, policy analysts, agriculture scientists, biologists), entrepreneurs, fish farmers and representatives of their associations, women's groups or their representatives, bankers, fishers, non-governmental organizations (NGOs), etc

(d) **Database**: it is important nationally to identify an institution, university, etc., as a focal point for analysis and custody of statistics in a database. The database will input into the subregional database and in turn this will input into a regional database. Information technology hardware and peripherals must be considered as paramount when selecting the national focal point.

(e) **Information**: there is a strong need for the promotion of information exchange throughout the region, in research, development, training and extension. This could be best done through networking. It would also contribute to reinforcing linkages between research and development at both national and regional levels.

THE WAY FORWARD – A STRATEGY FOR AQUACULTURE DEVELOPMENT

Within the context of the lessons learned, the Review prepared a 37-point aquaculture development strategy to be implemented over a period of five years (Box 2, page 34). The strategy included elements that could be initiated immediately with existing resources as well as others that would require changes or revisions of policies and additional funding. The eight points below encompass the principal issues:

1. *establish national development policies and an aquaculture development plan in consultation with stakeholders;*
2. *reduce expensive and unsustainable aquaculture infrastructure, specifically with a reduction of at least 50 percent of government fish stations within five years;*
3. *promote and facilitate the private sector production of feed and seed;*
4. *encourage credit for medium- and large-scale producers;*
5. *revise aquaculture extension, establishing a flexible and efficient structure that can meet producers' needs;*
6. *advocate farmer-friendly existing technologies that use readily available culture species and local materials;*
7. *promote collaboration, coordination and information exchange between national and regional aquaculture institutions and agencies; and*
8. *facilitate the formation of farmers' associations.*

The first step in the strategy is the elaboration of national aquaculture policies and development plans. This was a key recommendation of the Workshop 24 years ago. Yet, of the ten background country reports, eight indicated the lack of aquaculture policy as a recurrent problem while six stated there was also a lack of aquaculture planning.

To a great extent, policies and planning are a question of ***political will***. If there is the political will, formulation of appropriate policies and plans is within the capacity of nearly all countries in the Region.

For decades aquaculture in Africa has been vacillating between crests and troughs of various waves of development with the same constraints identified time and again: lack of seed, feed, credit and extension support. All of these constraints relate to the underlying lack of policy. If there is political will to establish workable policies, solutions to these other issues will be forthcoming.

Appendix II: Limbé Declaration[††]:

A consensus statement by delegates to the FAO/WorldFish Workshop on Small-scale Aquaculture, 23-26 March 2004, Limbe, Cameroon

Aquaculture development in sub-Saharan Africa is at a crossroads. Burgeoning population growth and declining natural sources of fish make it imperative that aquaculture make as substantial contribution to continental fish supply as possible. The region is the only one in the world where per capita fish consumption is declining and is projected to decline further. Reasons for this situation include: civil conflict, weak management structures, low levels of investment in rural economies, and lack of economic growth. At the same time, however, new opportunities exist that brighten the prospects for aquaculture development.

In many countries, policies of privatisation and decentralization provide incentives for increased investments in the sector from private and public sources as domestic markets, especially in urban areas, become more accessible and trade expands. At the global level, the ever-growing demand for fish has created opportunities for export-oriented aquaculture production. The challenge today is to make use of these opportunities for the sustainable development of aquaculture in the region. There is a need for a type of development that contributes to national food security and poverty reduction objectives and pays attention to the scope for expansion that the nature resource base allows.

Sub-Saharan Africa must, therefore, make a choice, either for "business as usual" and things continue as they are, and people live with the dire consequences, or it is "time to make hard choices", institute relevant policies and strategies, bring aquaculture into the formal cash economy and stem the tide that is undermining aquaculture's future. To this effect, many governments, cooperating partners as well as bilateral and multilateral development agencies are developing a new strategy for aquaculture development in sub-Saharan Africa.

The meeting recognized a number of constraints to the development of aquaculture, which include seed and feed production, as well as inefficient extension and outreach. The delegates to the workshop further acknowledge that:

- Support to a knowledge development and delivery structure to provide essential assistance for aquaculture from government and those providing external aide requires convincing demonstrations of impact on national development priorities such as poverty reduction, food security, nutrition, HIV/AIDS and sustainable environmental management;
- Institutional stability and durability will be achieved through structures that rely first and foremost on private sector investments as well as on output-orientated and accountable use of public revenue which aims at enhancing sustainable development of aquaculture; and
- Public/private partnerships between investors and knowledge delivery structures can facilitate sectoral growth by making available to farmers the highest quality technological, managerial and marketing information while public/civil society connections in such structures can help ensure the optimisation of public goods from the perspective of producers at all levels.

While appreciating the need to address the three major constraints identified (seed, feed, extension), the meeting called upon the governments and cooperating partners as well as research agencies to focus on the likely development impact of investment in these areas. In order to ensure optimum impact of the three development strategies, there is a need to examine other areas, such as market development, access to capital and other policy issues that might be deemed relevant and equally important.

[††] As published in CIFA Occasional Paper No. 25: Report of the FAO-WorldFish Center Workshop on Small-Scale Aquaculture in Sub-Saharan Africa: Revisiting the Aquaculture Target Group Paradigm, Limbé, Cameroon, 23-26 March 2004.

Furthermore, participants propose that SSA governments should seek to develop public/private partnerships within the growing number of aquaculture enterprises, by creating cost-effective financial and institutional arrangements that can compliment government and donor resources to deliver a limited number of critical research, advisory and technological services to high potential farmers.

Participants further pronounced that the approach to national aquaculture development, based upon the Cameroonian Strategic Framework for Aquaculture development addresses the major constraints to expansion of the sub-sector in the region, facilitates the necessary public/private and public/civil society linkages as well as proposes mechanisms to maximize returns to the investment of both public and private sector resources.

While endorsing this approach as an appropriate tool to foster aquaculture development, participants noted that such strategic approaches can only achieve their expected goals when efforts make use of existing national strategies, master plans and investment plans for aquaculture development in order to harmonize, building synergies and eliminating redundancies. These efforts involve national partners and stakeholders, but also aquaculture producers, support services, local authorities and investors from the public and civil society sectors, cooperating partners (donors), international and multilateral organizations.

The meeting envisages that aquaculture in SSA will grow into an important pillar of development in many areas in the region. It will be able to provide high quality food for rural and urban consumers, generate employment and general commercial activities in otherwise impoverished local economies, and contribute to national wealth through increased revenue from markets and trade. In order to achieve this vision, the countries in the region need to work together to increase their knowledge base, exchange best practice experiences and speak with one voice in the global marketplace.

Appendix III: Elements of the Cameroon Strategic Framework and the Role of Public and Private Sectors[‡‡]

Sustainable aquaculture development relies on a number of conditions that must be met and addressed in any strategy in a flexible way. The most prominent of these are: (1) suitable production systems; (2) availability and access to inputs (feeds, seed, capital, etc.); (3) outreach; (4) research; (5) education and training; (6) marketing; (7) producer organisations; (8) regulation; (9) control, monitoring and evaluation.

For each of the two types of aquaculture defined in this document (commercial and non-commercial), the following sections define the role of the public[§§] and private[***] sectors in meeting each condition. Unless otherwise specified, the role discussed applies to both commercial and non-commercial aquaculture.

In light of limited human and financial resources, Government is, in general, shifting, and should shift, from its role as a direct investor and development promoter to one as a facilitator of an independent and commercially viable aquaculture sub-sector. The private sector is composed of two general groups of actors: direct investors, including producers along with service providers, and partners, principally producer organisations and Civil Society Organisations.

1. Suitable production systems

Government should:

- identify general production technologies appropriate to relevant aquaculture zones;
- inform investors in regard to these technologies; and,
- concentrated its outreach activities in these zones.

The private sector should:

- be aware of the Government strategy regarding different production systems within aquaculture zones.

2. Availability and access to inputs

a) <u>Feeds[†††]</u>:

Government should:

- stimulate domestic feed industries by reducing or removing taxes on imported feed milling machinery and basic feed ingredients;
- make information on feed and feed materials, especially prices, regularly available to producers through all means of information transmission;
- within its means, ensure feed quality through inspections and feed certification;
- promote the adoption of appropriate feed manufacturing guidelines such as the *FAO Technical Guidelines for Good Aquaculture Feed Manufacturing Practice*; and,
- encourage commercial farmers and millers to facilitate access to quality feed for the entire sub-sector.

Direct investors (feed mills) should:

- produce and market necessary feedstuffs to growers;
- provide a uniform quality products at a fair price;
- find mechanisms to facilitate access to high quality feed throughout the sub-sector;
- make proximate analyses available to clients;
- provide information on feed availability and efficacy to the public sector;

[‡‡] Strategic elements as adopted by a National Stakeholders Seminar in December 2003.
[§§] Includes the ministry in charge of aquaculture, the national research institute, and the government extension service.
[***] Includes producers, investors (in both fish farming and related sectors), non-governmental organizations (NGOs), commercial banks, universities and development agencies.
[†††] Including commercial and tradable feeds, feed materials and other nutrient inputs.

- as appropriate, assist outreach programme in promoting good feeding practices/fish management; and,
- monitor results.

Producer organisations should:

- serve as a forum for information sharing among stakeholders;
- lobby for collective bargaining and appropriate public sector intervention; and,
- link with research organisations.

b) <u>Seed:</u>

Government should restrict itself to:

- providing regular information on sources and prices of good quality seed to producers;
- providing guidelines in producing/ensuring good quality seed through such measures as seed certification;
- maintaining broodstock of selected culture organisms corresponding to the identified production systems; and,
- encourage commercial farmers and hatcheries to facilitate access to quality seed for the entire sub-sector.

Direct investors (seed producers) should:

- produce and distribute quality seed;
- sell products at a fair price;
- find mechanisms to facilitate access to high quality seed throughout the sub-sector;
- as appropriate, assist outreach programme in promoting good management practices favouring improved yields; and
- monitor results.

Producer organisations should:

- serve as a forum for information sharing among stakeholders;
- lobby for collective bargaining and appropriate public sector intervention; and,
- link with research organisations

c) <u>Capital</u>:

Providing and managing credit by the Government often leads to conflicts. Thus, in terms of investment capital for commercial aquaculture[‡‡‡], Government should restrict itself to creating an enabling environment, through, for example:

- the provision of information to lending agencies on the profitability of aquaculture[§§§];
- evaluating the technical merits of investment proposals submitted to lending agencies for funding;
- advising farmers on where and how to access funding from specialised institutions; and.
- interacting with these funding institutions to negotiate preferential interest rates for aquaculture development as appropriate.

The private sector should:

- in addition to their own equity, commercial producers should rely on private sector funding institutions for capital;
- lending institutions should consider preferential interest rates for aquaculture enterprises when applicable;
- investors requesting credit support should prepare clear and precise business plans;
- formal lending institutions should finance viable aquaculture businesses;

[‡‡‡] Credit is not generally considered appropriate for non-commercial aquaculture (FAO 1999).
[§§§] Relevant information from a variety of sources should be collated by research agencies for this purpose.

- small investors should ensure that they have appropriate business and financial management skills before requesting external financial support; and,
- NGOs should work with non-commercial producers to develop financing options;
- collect information on other funding mechanisms and make it available to farmers;
- sensitise farmers on the savings and solidarity funds for use in aquaculture development;
- examine the possibility of creating an aquaculture guarantee fund;
- examine the possibility of providing temporary direct assistance to aquaculture producer organisations.

3. Outreach

Government should:

- provide quality technical assistance through an efficient aquaculture outreach program;
- seek partners as necessary to meet information shortfalls that cannot be met with public resources;
- establish national and international aquaculture information networks which are accessible at local hubs;
- play a co-ordinating role in the outreach programme;
- put emphasis on participatory approaches when providing services to farmers;
- encourage group formation for purposes of rationalising marketing and purchase of inputs, as well as increasing outreach-farmer contact;
- encourage commercial investors to provide outreach support to smaller operators;
- facilitate the creation of discussion channels amongst different aquaculture stakeholders; and
- require larger investors to pay for the technical assistance on a contract basis, negotiated with the institution providing assistance.

The private sector should:

- assist and reinforce public sector outreach programmes, particularly with regard to outreach contributions by feed and/or seed suppliers;
- evaluate outreach efficacy and advise as to outreach needs;
- feedback to public sector as to available information sources;
- commercial producers should pay for technical assistance; and,
- commercial producers should assess their opportunities in serving as information providers.

4. Research

For commercial aquaculture, Government should:

- support applied and farmer-participatory research directed at small and medium scale commercial farmers;
- ensure that research is responsive to the needs of farmers[****]; and,
- develop methods whereby farmers at the upper limit of the spectrum (i.e., large-scale, capital intensive systems) have access to Government research facilities and scientists on a contract basis.

For non-commercial aquaculture, Government should:

- fully fund research for systems operated by low-income farmers.

The private sector should:

- fund research;
- disseminate research results, as appropriate; and,
- evaluate research results and inputting into research agendas.

5. Education and training

Government should:

- develop specific curricula for practical training of entry-level farm managers and aquaculture technicians;

[****] Researches' merit increases should be linked to on-farm results rather than publication record.

- arrange and/or conduct on demand at regular intervals, short courses for in-service training and human resource enhancement;
- establish a continuing training plan for its staff and assist in linking candidates with local, regional or international agencies providing training, education and/or financial assistance, including distance learning options;
- provide information on career development in aquaculture; and,
- introduce longer term, professional training in aquaculture sciences to universities.

The private sector should:

- pay for training of those technicians necessary for the development of a commercial aquaculture sector;
- facilitate training opportunities on their farms; and,
- feedback to the public sector regarding the efficacy of training; materials/curricula, advising on training needs as necessary.

6. Marketing

Government should:

- make information on fish retail prices, conservation and traitment available to producers and consumers through, for example, newspapers, newsletters, rural radio or other media;
- protect local producers against unfair foreign competition (imports) provided that protective measures used fit within the international trade conventions/agreements;
- provide basic marketing infrastructure, such as roads and communication channels;
- assist producers in promoting aquaculture products (in order to stimulate demand) through agricultural fairs and other such opportunities;
- encourage commercial producers to develop market channels which can be accessed by smaller producers; and,
- prepare, publish and regularly monitor guidelines on the implementation of quality standards of aquatic products to protect the public health as well as improve acceptability of aquaculture products.

Commercial producers should:

- provide uniform quality products according to market requirements; and,
- look for mechanisms to provide market guarantees for smaller producers (e.g., satellite production systems).

7. Producer organisations

Government should:

- promote and facilitate the formation of producer organisations with legal status as appropriate by, for example, advertising their advantages in collective bargaining, streamlining administrative the registration process, etc.; and,
- advise interested farmers, feed and seed producers on where and how to get assistance in group formation and function.

The private sector should:

- producers should organising themselves to defend their mutual interests, facilitate access to inputs and markets, etc.;
- NGOs should play a catalytic role in establishing producer organisations; and,
- organisations should consider establishing a national producer organisation assembling the local organisations.

8. Regulation

Government should:

- establish clear and secure user rights to land and water favourable to aquaculture investment;
- avoid unnecessary costs on applicants in acquiring necessary rights to land and water and the right to undertake aquaculture operations;

- regulate the movement of aquatic organisms between watersheds and the provision of discharge and outfall standards (e.g., *Biological Oxygen Demand-BOD* limits or alien species to receiving water bodies, etc.);
- regulate the use of alien and genetically modified aquatic organisms;
- for commercial aquaculture farmers, require permits which specify their rights and obligations;
- waive such permits for non-commercial aquaculture as long as Government regulatory thresholds are not exceeded;
- adopt a one-stop shop for obtaining permits and information relevant to aquaculture development;
- collect and publish reliable and up-to-date statistics; and,
- apply and enforce appropriate international codes to which Government subscribes (e.g., *Code of Conduct for Responsible Fisheries* – CCRF);
- determine criteria for requiring environmental impact assessment studies ;
- regulate seed production ;
- regulate the production of commercial feed production;
- define a regulation on quality control of aquaculture products.

The private sector should:

- be aware of relevant regulations;
- self regulate to ensure good farm management practices with the goal of sustainable resource use;
- self regulate to ensure a safe-to-consume product is provided to all consumers; and,
- provide complete and correct data for monitoring by the public sector.

9. Control, monitoring and evaluation

Government should:

- control the movement of aquatic organisms between watersheds and the provision of discharge and outfall standards (e.g., *Biological Oxygen Demand-BOD* limits and alien species to receiving water bodies, etc.);
- control the use of alien and genetically modified aquatic organisms;
- for commercial aquaculture farmers, require permits which specify their rights and obligations;
- apply and enforce appropriate international codes to which Government subscribes (e.g., *Code of Conduct for Responsible Fisheries* – CCRF);
- define a standard system for statistics/data collection and treatment;
- collect and publish reliable and up-to-date statistics;
- control whether or not, where necessary, environmental impact assessment studies are properly conducted;
- control seed quality;
- control the quality of commercial feeds;
- enforce the regulation on quality control of aquaculture products.
- regularly evaluate the sector development level.

The private sector should:

- respect regulations on the movement of aquatic organisms between watersheds and the provision of discharge and outfall standards;
- respect regulations on the use of alien and genetically modified aquatic organisms;
- seek permits before establishing a commercial aquaculture farm;
- apply appropriate international codes to which Government subscribes;

- regularly provide reliable and up-to-date statistics;
- have self-regulatory, self-control mechanisms to ensure seed quality, the quality of commercial feeds and the quality of aquaculture products.

SPECIFIC ISSUES

1. Government Stations

One or more government stations should be maintained for training, fish genetic management, and research. The criteria for maintain a station should include, inter-alia, its economic viability, the needs for genetic conservation, research and training as well as zones with high aquaculture potential. Following the existing (draft) government master plan for aquaculture, other economically viable government infrastructure should progressively be sold or leased long-term ***as is*** to a well chosen private sector according to existing laws and procedures on the sale or lease of public property. Non-viable infrastructure, or those stations for which no buyer or lesser can be found, can be donated to such public institutions as schools, prisons or orphanages. Public sector technical services should be able to assist potential buyers or lesser in determining the economic potential of these facilities.

2. Marine and Coastal Aquaculture

Mariculture and other coastal production systems are strategically no different from inland systems and the same processes should be applied. However, it should be recalled that coastal regions comprise critical ecosystems which are highly productive though fragile, requiring careful environmental considerations. Also, these areas are complex socio-economic zones where the potential for conflict over use is high and whose economic contribution to livelihoods is highly significant. The existing body of knowledge for best practices for integrated coastal management should be applied[††††].

3. Non-conventional aquaculture systems

The culture of ornamental species should, as well, be considered among the multiple aquaculture systems practised in the country. Organically certified aquaculture, growing aquatic plants, etc. are also examples of non-conventional systems.

4. Unexplored Culture Species, Introductions and Genetically Modified Organisms

Mainstream aquaculture species are tilapias, catfish, carp and *Heterotis* along with a few minor cichlids. The establishment of presently unexplored culture species may have a high economic cost to be able to develop the required seed multiplication and distribution networks. Thus, the promotion of new culture organisms must take these costs into consideration.

Introductions of alien species need to adhere to international conventions and covenants.

Control of genetic integrity of aquatic organisms is an important issue, which is frequently addressed under the rubric of aquaculture. Reference has been made above to precautionary procedures that are advised, however is it noteworthy that the overall pond management needs to be significantly enhanced before any benefits of genetically modified organisms can become apparent.

[††††] (GESAMP 2001).

Appendix IV: The NEPAD Action Plan for the Development of African Fisheries and Aquaculture[‡‡‡‡]

Executive Summary

NEPAD recognises the vital contributions by African inland and marine fisheries to food security and income of many millions of Africans and to poverty reduction and economic development in the continent. It further recognises the growing opportunities and emerging successes of aquaculture development in the region. Within the framework of the Comprehensive Africa Agriculture Development Program (CAADP), a series of regional technical consultations were held that identified the primary areas for investment to safeguard and further increase these benefits, together with a first set of priority actions in each. The *NEPAD Action Plan for Fisheries and Aquaculture Development in Africa* describes these investment areas for inland fisheries, coastal and marine fisheries, and aquaculture:

For Aquaculture:

- Developing sector-wide strategies at national level for expansion and intensification of aquaculture
- Supporting priority aquaculture zones
- Encouraging private sector investment across the sector
- Applying proven technologies to increase production
- Maintaining the competitive advantage that Africa's environment provides for aquaculture production
- Harnessing the opportunities for small and medium enterprise development provided by expanding domestic markets for fish, including growing urban demand
- Supporting the emerging regional trade in aquaculture products
- Harnessing the opportunity of expanding export markets for high-value products to increase investment in African aquaculture production and processing
- Expanding the adoption of integrated small-scale aquaculture as a means of increasing rural productivity and food security
- Exploiting the potential of aquaculture production to contribute to food security programs

If investments are made across these areas it is projected that the stagnating or declining fishery production in the region can be stabilized and in a few cases expanded. By improving processing and access to regional and global markets through improved policies and public-private partnership investments in quality control capacity, market information systems, and sector management, it is expected that their contributions to socio-economic development can be enhanced and diversified. In the case of aquaculture, substantial growth in sustainable production can be achieved.

To guide these investments and enhance sustainability of impact, several cross-cutting areas need to be supported. These include the development of sector-wide strategies for fisheries and aquaculture using economic planning approaches and a comprehensive value-chain perspective. Regional capacity for research and development needs to be strengthened; and technical expertise in the region needs to be supported through networking and improved communications.

It is proposed that implementation of this Action Plan should follow a 'piloting' approach with Fast-track Programs to be identified for immediate action. These should focus on areas of strategic regional importance and current growth and will provide a learning process for subsequent expansion of activities. In addition, it is essential that pertinent lessons and experiences from other regions and sector are effectively applied to accelerate the development of African fisheries and aquaculture.

This Action Plan serves as an Africa-wide framework for developing specific interventions by stakeholders at Regional Economic Community and national levels, taking into account their on-going initiatives and development priorities. This will enable these stakeholders to draw on NEPAD – CAADP for expanding the scope of their successful initiatives, addressing critical capacity and strategy needs, and linking with relevant knowledge and technologies in other regions of Africa.

African Fisheries and Aquaculture

Africa currently produces 7.31 million tons of fish each year. Of this 4.81 million tons is from marine fisheries, and 2.5 million tons from inland fisheries. While capture fisheries rose steadily throughout the 1980s and 1990s they have stagnated since then, reaching about 6.85 million tons in 2002. Aquaculture on the other hand has risen, but slowly, and only in Egypt has growth achieved rates of increase seen in other parts of the world, rising

[‡‡‡‡] **NEPAD-*Fish for All* Summit, Abuja, Nigeria, 22-25 August 2005**

from 85,000 tons in 1997 to over 400,000 tons in 2004. These trends combined with population growth mean that per capita consumption of fish in Africa is low and stagnating, and in sub-Saharan Africa specifically per capita consumption has fallen in the past twenty years. In a recent study by IFPRI and the WorldFish Center analysis of future demand and supply of fish suggested that if per capita consumption is to be maintained at present levels up to the year 2020, capture fisheries will need to be sustained and where possible enhanced, and aquaculture developed rapidly, with an increase of over 260% in sub-Saharan Africa alone over the course of the next 16 years.

While these trends underline the enormous internal demand for fish in Africa, they also highlight both the importance of managing capture fisheries more effectively so that their full development potential can be achieved and sustained, and the urgent need to foster more rapid development of aquaculture. For capture fisheries there is growing recognition that improved governance systems for fisheries resources and better management of the resource base upon which they depend are needed for sustainable use, while carefully targeted investments in infrastructure and marketing are needed if the full value of these resources is to be realised by the local, national and regional economies.

In addition studies by FAO have shown that there is considerable physical potential to respond to the growing demand for fish by improving aquaculture production. For SSA alone it is estimated that 9.2 million km^2, or 31 per cent of the land area, is suitable for smallholder fish farming. If yields from recent smallholder development projects can be replicated elsewhere, only 0.5 per cent of this area would be required to produce 35 per cent of the region's increased fish requirements up to the year 2010. At present however this potential for aquaculture remains largely untapped. By 2002 total aquaculture production in SSA was only 79,500 t, 0.15 per cent of world production, yields in most countries remain low, commercial operations have yet to develop in many areas, and fish farmers are relatively few in number. However, the main economic parameters are starting to change and opportunities for aquaculture are opening up. With growing urbanisation, improved market integration and the concurrent supply crisis from capture fisheries, small and large scale investors are gaining interest in aquaculture production. There is urgent need to develop guidelines and policies that create a conducive aquaculture investment climate and at the same time provide safeguards against environmental and social risks.

Trade in fish products has increased substantially over the past two decades and African fish exports were valued at US$ 2.7 billion in 2001, from a total global value of US$ 56 billion. Much more can be done to foster markets for African fish products, both within the region and globally. In several countries, fish exports to European and other overseas markets are now contributing significantly to national economies. In a relatively short time, the fish processing and exporting industry has acquired access to tightly regulated markets by meeting international HACCP and SPS standards. There is great potential to learn from these success stories and build the capacity of a wider spectrum of small and medium-sized enterprises to participate in these growth opportunities.

At the same time, trade relations with importing countries need to develop further to stimulate the growth of value-adding industries in Africa. In marine fisheries, arrangements that regulate the access of foreign fleets to African fish stocks need to be considered from a long-term perspective on fish supply and economic development opportunities. Though the export of fish from Africa is an important economic activity for many countries, marketing fish locally needs to be encouraged as this will contribute significantly towards the reduction of hunger and malnutrition as highlighted in the Millennium Development Goals. Clearly, the implications of accelerated fish trade for poverty and food security need to be fully understood so that the potential of trade as a stimulus to fisheries development can be effectively harnessed. Importantly, this will include increased attention to domestic and regional markets in addition to exports to industrialised countries. Trade of fish between African countries is an important if often unreported sector that provides affordable fish products to millions of consumers across the continent. It is estimated to absorb up to 50% of fish catches in some inland fisheries and it is widely acknowledged that better processing, improved transport and marketing, and more conducive regional trade relations could increase the contribution of this trade to the regional economy and food security. Gaining a wider and more balanced perspective on opportunities for trade at all levels will be an important step towards maximising the development impact of fish exports to regional and global markets.

Fisheries and Aquaculture in the Nepad Process

The NEPAD process prioritises key areas of agricultural and commercial development for accelerated implementation. Several among them intersect with fisheries and aquaculture development. In the agriculture pillar, the *Comprehensive African Agriculture Development Programme (CAADP)* has identified four strategic thrusts:

(i) extending the area under sustainable land management and reliable water control systems;
(ii) improving rural infrastructure and trade-related capacities for market access;
(iii) increasing food supply and reducing hunger; and
(iv) agricultural research, technology dissemination and adoption.

In all four areas, fisheries and aquaculture have achieved successes at local and national levels that can be scaled up regionally. Aquaculture has proven to improve water management practices at community and farm level, thus increasing returns from crop production in drought prone regions in southern Africa. Marketing of fish products, especially from small-scale capture fisheries, has opened many remote areas to wider markets, in the process enhancing market involvement of rural producers. Fish also contributes substantially and cost-effectively to nutrition security by supplying protein and other vital nutrients to the diets of 200 million Africans. Finally, aquaculture research, technology development and transfer are making a growing contribution to increasing fish supply and have the potential to widen their impact substantially in future. The recent success of commercial aquaculture in Egypt, which today contributes 50% of domestic fish supply, exemplifies opportunities for transferring such technologies within Africa.

With growing demand for fish and stagnating supply figures, there is an urgent need to now build on these success stories in developing a regional approach to fisheries development. In its efforts to identify opportunities arising from particular sectors and initiatives, the CAADP Action Plan has recognised the importance of fisheries in the region and the potential for development of aquaculture. There is considerable potential to include a plan for Fisheries and Aquaculture Development amongst the "flagship programmes" of the Action Plan to further guide the fisheries sector's key contributions to the CAADP priorities.

In doing so fisheries development can also contribute to objectives and programs in other NEPAD pillars. The *NEPAD Market Access Initiative* emphasizes the competitiveness of African economies in global markets and the enhancement of intra-African trade. In both areas, fish has become a leading commodity, with an export value of US$ 2.7bn annually for Africa as a whole. The full potential for a vibrant fish trade in and beyond Africa has, however, not yet been realized. With fish demand projected to rise substantially on the continent as well as globally, the long-term prospects for African fish products are very promising. Building on the successes of fish processors and exporters in several countries, the private sector is now presented with tremendous opportunities in capture fisheries as well as the aquaculture sector. Further investments need to be directed towards assessing fish supply and demand trends, developing conducive fish trade policies, improving market infrastructure, and building capacity among fish producers and processors for continued technical innovation, market exploration and self-regulation. These investments should include public-private partnerships that will support business development across the continent while also safeguarding wider poverty reduction objectives through involvement of small-scale entrepreneurs and attention to regional markets.

Further, the *NEPAD Environment Action Plan* has prioritised the 'conservation and sustainable use of marine, coastal and freshwater resources' as well as 'cross-border conservation or management of natural resources'. Both objectives are of critical importance to the future of fisheries and aquaculture. Investments into developing environmental safeguards for the expansion of aquaculture and improving management of wild fisheries resources will be key contributions by the fisheries sector to overall environmentally sound management of aquatic resources.

The Action Plan

The overall technical objectives of the Action Plan are:

1. To support, and where possible increase, the long-term productivity of African fisheries and aquaculture through sustainable use of aquatic resources and application of environmentally sound technologies;

2. To strengthen food security and trade benefits for Africa's socio-economic development through improved access of African fish products to domestic, regional and international markets.

Context

Aquaculture has grown strongly in most regions of the world where the potential exists. This has not happened in sub-Saharan Africa, and Egypt is the only African country to have achieved the scale of change observed elsewhere. However there is now growing recognition that aquaculture in Africa can develop under specific conditions and contexts, and that the prospect of market-led growth and broader regional integration, together with more realistic understanding of the technical potential, provides substantial opportunities for growth.

This realisation has promoted considerable development investment and sectoral promotion at both regional and national levels. The availability of natural resources and the opportunities for entering valuable export markets have also led to private investment initiatives, often with external capital, in wholly owned enterprises, or joint ventures. In many circumstances, local private investment has also been considerable, often by artisanal farmers, community development association and local businesses, with expectations of meeting local demand and diversifying household income. The challenge being addressed now in many countries is how best to foster this growth.

Improved Productivity

Investment Area 1. Developing sector-wide strategies at national level for expansion and intensification of aquaculture

The importance of having a viable sector strategy at national level is increasingly realised. Based on a better understanding of the structure of the sector, this involves targeting support to the different needs and strengths of small, medium and large scale aquaculture enterprises. The role of private sector investments in pursuing such a strategy is a key issue that will decide on the level of growth and sustainability of support services. In doing so it is essential that available experience and lessons from other regions are being utilized to drive the development of aquaculture in Africa. This applies in particular to other developing country experience in areas of production, environmental management, trade relations, market development and public private partnerships. One of the limitations of past approaches in Africa has been the neglect or ineffective use of this knowledge base. On the basis of regional cooperation through RECs and NEPAD, African countries and aquaculture stakeholders can strengthen their international linkages in these areas and use available expertise to build up their own capacity.

Action points:

- Develop national aquaculture sector strategies based on economic planning and value-chain approaches, including targeted strategies for small and medium scale, as well as large scale industry
- Review international lessons on aquaculture sector, in particular from Asia, and their implications for Africa
- Agree among stakeholders on a phased approach to sector development, with immediate action taken up over the next months
- Adopt current standards of valuation and investment planning for the sector at national level
- Establish a regional network of aquaculture policy practitioners, supported by other leading government planning sectors, to accelerate the development of aquaculture strategies and their integration into wider economic strategies at national level

Investment Area 2. Supporting priority aquaculture zones

Aquaculture is not developing evenly across the continent; instead, priority areas with high natural, economic and social potential are beginning to emerge. These include priority resource systems (such as particular lakes or coastal areas), peri-urban zones, areas with existing processing capacity, and clusters of rural aquaculture. These need to be further assessed within the context of regional and ecosystem planning, and immediate support needs to be focused on these areas. Links and synergies with commercial agriculture development need to be pursued, for example for supplying crop-based feeds in large quantities. A process will need to be established for addressing governance issues around competing resources uses and access rights, and monitoring of longer-term impact of such priority zones.

Action points:

- Immediately identify priority zones through rapid assessments, taking into account natural, economic and social factors of growth and innovation
- Supplement this through GIS based surveys of further potential growth areas
- Assess current and future demand for raw materials for feed and fertilizers and pursue linkages with agriculture development for establishing supply-chains for aquaculture
- Review governance and resource access implications of priority zones

Investment Area 3. Encouraging private sector investment across the sector

In response to growing demand for fish products, private sector investment interest has substantially increased in the region. This interest needs to be supported and private investments guided towards sustainable growth. Public private partnerships offer a variety of options to deliver support services and management functions that are critical for sector development, including information, R&D, monitoring, regulatory and financial support. Strategic public investments are justified to improve the policy and legal framework and facilitate exchange and lesson learning across the continent. In advancing and expanding aquaculture, however, the private sector needs to take the leading role, and this needs to be recognised in strategy development and investment planning.

Action points:

- Link aquaculture investors at all levels to national and regional enterprise development programs.
- Review lessons and experiences of public-private partnerships from other sectors and regions.
- Review policy, regulatory and legal frameworks with a view to support private sector opportunities, in particular for small and medium-scale enterprises
- Encourage private-public partnerships in support of research, training and technology development

Investment Area 4. Applying proven technologies to increase production

Technologies for increasing productivity at different levels of investment, expanding aquaculture zones and improving product quality are available from many regions, including Africa itself. Constraints exist in access and application, including purchasing and operating costs, technical skills, disease and other risks in intensive systems, and biosafety concerns in the case of new species. Support is needed to improve information, dissemination, application and risk management capacity in the region. This support area offers significant opportunities for private sector investments.

Action points:

- Immediately identify technologies available in the region with potential for wider dissemination and application, including advances in commercial production in Egypt and in integrated smallholder systems in Malawi.
- Establish and support private sector led technology dissemination and application services.
- Support regional networks of aquaculture service providers, including research and technology dissemination, for scaling-up local and national successes
- Support private sector capacity to deliver advanced monitoring and risk management services.
- Strengthen the capacity of tertiary and research institutions in Africa to provide science and training services required for longer-term technology development, and strengthen their linkages with private sector initiatives

Environmental Sustainability

Investment Area 5. Maintaining the competitive advantage that Africa's environment provides for aquaculture production

The relatively intact natural environment in most African countries offers a comparative international advantage for Africa as an aquaculture production region. This advantage needs to be fully assessed in terms of resource value, production options and marketing strategies for African aquaculture products. It is important that this 'capital' is further supported through good governance of aquatic and land resources, and that lessons from other regions in the developing world (in particular Asia) are effectively applied to avoid mistakes and achieve sustainable growth.

Action points:

- Assess competitive advantage of different African environments and product ranges.
- Review lessons and experiences of aquaculture resource degradation from other regions, in particular Asia.
- Identify policy needs and institutional linkages with environmental, water and related sectors at national level.

Market Development and Trade

Investment Area 6. Harnessing the opportunities for small and medium enterprise development provided by expanding domestic markets for fish, including growing urban demand

The widening supply and demand gap for fish in most domestic markets in Africa offers growing opportunities for aquaculture production. There is immediate need to assess the range of products, seasonality and price elasticity and substitution effects in these markets and to target aquaculture production, harvesting and marketing strategies accordingly. In many cases, aquaculture products are not differentiated from capture fisheries products and may therefore miss out marketing advantages and price premiums. Market information, marketing skills and logistics need to improve significantly for aquaculture enterprises to fully utilise this area of opportunity.

Africa is the most rapidly urbanising region in the world, and urban populations have an increased demand for fish. To meet this demand, small and medium-scale aquaculture enterprises are emerging in peri-urban zones, and rural producers are marketing their products increasingly in urban markets. There is growing need, therefore, to assess the full potential and structure of urban fish and food markets and accordingly support peri-urban zones as priority aquaculture areas. Enterprise development in production, support services and marketing, regulatory framework, market infrastructure development are key constraints at this time. Correspondingly, market access for rural producers needs to improve. As urban demand becomes more differentiated, it will become increasingly important to see what segment of the market aquaculture – and fish supply more generally - can target effectively.

Action points:

- Assess the longer-term trends and current structure of domestic supply and demand, including urban demand, product range and price elasticity
- Support the development of practical market information mechanisms
- Support small and medium scale enterprises through technical advice and financial services to access local, urban and wider domestic markets with a targeted product range

  Provide enterprise development support to small and medium scale operators to further develop their businesses towards market integration
- Review policy, regulatory and legal frameworks with a view to support further opportunities for small and medium-scale enterprises in production and service industries

Investment Area 7. Supporting the emerging regional trade in aquaculture products

There is immediate need to assess the current structure, volume and economics of fish trade between countries in the region, addressing in particular the 'informal' trade of low-value fish that appears to be a substantial sector supplying food to millions of people and providing very strong business opportunities for women entrepreneurs. Aquaculture products are increasingly entering these trade routes as processed or fresh products, in some cases to be further processed and re-exported in the region and beyond. These market opportunities need to be supported through better cross-border information systems, conducive regulatory and policy frameworks, and enterprise development support targeting women in particular. The RECs will play an important role as coordinating agencies.

Action points:

- Assess and document the current structure, volume and economics of intra-regional trade of low-value food fish
- Support women entrepreneurs in this sector through technical advice and financial services to further invest in post-harvest and trade of aquaculture products in regional markets
- Review policy, regulatory and legal frameworks with a view to further strengthen opportunities for women in small and medium-scale enterprises

Investment Area 8. Harnessing the opportunity of expanding export markets for high-value aquaculture products to increase investment in African aquaculture production and processing

The emerging success of African aquaculture exports needs to be further supported through investments in policy, legal frameworks and support services. In particular, capacity has to be strengthened in the region for quality control to meet changing food safety and traceablity requirements of import markets. Public private partnerships provide viable options for financing such investments. There are opportunities emerging for small and medium-scale enterprises to participate in aquaculture export trade at various stages in the production and marketing chain, and these need to be supported through enterprise development and linking into niche markets. Options for labelling and certification schemes – including 'organic' production - need to be assessed and experience form other sectors and regions utilised in order to gain a realistic and workable perspective on these instruments. Links with existing export marketing of capture fisheries products are being pursued by individual enterprises. There is also further need to improve information flow on markets, prices and standards to enterprises and investors in the region.

Action points:

- Assess options for public-private partnerships for management and financing of this sector, using experiences from other export sectors and regions
- Where possible, support associations of small and medium-scale enterprises to participate in this sector, based on lessons from other regions and sectors
- Establish a regional aquaculture industry association to facilitate coordination, R&D and market development
- Encourage investments in value-added industries through conducive trade and market access conditions for value-added products from Africa

Food Security and Nutrition

Investment Area 9. Expanding the adoption of integrated small-scale aquaculture as a means of increasing rural productivity and food security

Successful examples of Integrated Aquaculture Agriculture, raising farm productivity and incomes by combining fish farming with crop, livestock and small-scale irrigation, are available from Southern Africa and need to be scaled up and adapted for the region. This will be a significant contribution to food security among smallholder farmers. To achieve this, scaling-up tools and approaches need to be improved and linked with rural development agencies outside the aquaculture sector, such as NGOs. At a commercial level, options for further intensification of such integrated systems, in particular in combination with irrigation, need to be explored. In addition, opportunities and viability of stocking of dams and small water bodies, in particular in food insecure dry regions, need to be assessed and workable approaches developed.

Action points:

- Immediately identify and apply approaches for scaling-up successful integrated aquaculture practices from Malawi in other countries in Southern Africa
- Support further research and development to intensify these integrated systems and adapt them to new water and land environments
- Support integration of aquaculture and agriculture research and planning in the context of growing investments in irrigation schemes

- Assess the viability of stocking and stock enhancements of dams and small water bodies in food insecure regions

Investment Area 10. Exploiting the potential of aquaculture production to contribute to food security programs

The nutrition benefits from aquaculture - and fish consumption more generally - need to be fully documented and promoted through education and health programs focusing in particular on women as key decision makers. Benefits for vulnerable populations, including children, women and people affected by HIV and AIDS, need to be targeted and small-scale aquaculture production and marketing strategies adjusted accordingly. To spread food security benefits more widely, aquaculture needs to be linked better with food security and school feeding programs at national or regional level, including NEPAD's programs. Strategically, aquaculture development may be viewed as a long-term investment in food security by increasing levels of control and management of fish and aquatic resources.

Action points:

- Assess and document the nutrition benefits of common fish consumption among vulnerable populations, including women, children and people affected by HIV and AIDS
- Support health and rural development agencies to include promotion of fish consumption into their community programs
- Link small and medium-scale aquaculture enterprises as suppliers with national school feeding programs to improve child health and nutrition

Appendix V: Case in Point – Aquaculture Development in the Lake Basin Area of Kenya[§§§§]

PROJECT HISTORY

In 1982, a UNDP/FAO Preparatory Assistance Mission concluded that there was an immediate need for more rapid and intense assistance for the development of small-scale fish farming in the Lake Basin Region. However, due to limitations on UNDP's financial resources at that time, the Government of Kenya requested and was granted assistance under project TCP/KEN/2303 to initiate a training programme for Lake Basin Development Authority (LBDA) fish farming extensionists.

In the course of the subsequent projects KEN/80/006 and KEN/86/027 ("Development of Small-Scale Fish Farming in the Lake Basin Area"), supported initially by UNDP and FAO and later joined by the Belgian Survival Fund (BSF), executed from 1985 to 1994 by FAO and implemented by LBDA, fish culture was introduced in the rural zones in order to combat protein deficiency in the area.

During the implementation of these projects thousands of fish farmers constructed ponds which were supplied with fingerlings from eight Government Fry Production Centres (FPC's) and from several private fingerling producers in the area. First trials with formulated feeds were promising. The latter project also introduced Clarias rearing as a more profitable activity. However, after ten years of assistance, fish farming still seems to be partially established in Western Kenya.

Before a decision was taken of a third and last intervention in order to insure the viability and sustainability of the action, a Technical Review Mission (TRM) was mandated to evaluate the past activities and formulate, if necessary, a new document for a third phase. This was carried out in 1995. Among its conclusions, the TRM noted that most of the fish farmers appear to be dependant on external assistance, particularly from the project and from LBDA. However, a few fish farmers were not only growing fish as a source of protein, but were beginning to show interest in profits and increased income from this activity.

BSF on one hand and UNDP on the other hand agreed that the project was not yet sustainable enough and therefore a last final intervention should be made in order to attain its objectives. Fish culture has to be successfully introduced as a rural economic activity, with a critical mass of well-trained, advanced commercial fish farmers, who can provide a reservoir of skills and services to fellow grass-root small-scale fish farmers – the target beneficiaries – so that sustainability may be assured even without major continuous institutional/governmental assistance and inputs.

After the completion of the project KEN/86/027, the Government of Kenya (GOK) requested assistance from FAO's Technical Cooperation Programme and the project TCP/KEN/45551 "Support to Small-Scale Rural Aquaculture in Kenya" was approved by FAO in February 1995 to further support the initiatives made and to reinforce progress towards sustainability of rural fish culture production while the third phase was being formulated. This TCP project was initiated in April 1995 for a period of nine months, later extended to 12 months, and subsequently to 21 months (December 1996).

In March 1998, following a request from the GOK, a third and last phase of assistance started under the form of the project GCP/KEN/060/BEL "Consolidation of Sustainable Small-Scale Fish Farming Enterprises", executed by FAO in the framework of its agreement with the Belgian Government, the donor [Belgium Survival Fund; BSF]. The project was designed as a two-stage exercise: the initial phase of 12 months – the Preparatory Stage – was intended to concentrate on socio-economic and marketing issues through implementation of a set of studies (socio-economic survey, PRA, marketing, cost-benefit analysis and nutritional studies) to allow the analysis of the impact of the project and assess present and future trends, and to generate a revised project document for the second phase – the Implementation Stage - which corresponds to the consolidation of past achievements.

GCP/KEN/060/BEL has been concurrently executed with the UNDP capacity building component of the Preparatory Stage, KEN/97/004 project (under National Execution up to June 1999) whose emphasis is placed on sustainable human resources development through training. The component related to the cost-benefit analysis studies was handled as a joint exercise contributing to both project components.

[§§§§] **Excerpts from:** Report on Project GCP/KEN/060/BEL,May 5 – June , 2000, Dr. Les Torrans, FAO Consultant USDA/ARS/CGRU, P.O. Box 38, Stoneville, MS 38776 (USA)

In November 1999 the 12-month preparatory phase of the final term of BSF support was completed – this phase was to lead into a terminal 24-month Implementation Phase after which the BSF would consider the project completed. A review mission was held in December 1999 between the Preparatory Phase and the Implementation Phase to assess the design of the Implementation Phase and recommend whether or not this phase should be funded by BSF.

The review concluded that an additional terminal phase was necessary and even accepted that this could be in the neighborhood of 48 rather than 24 months, but identified a number of areas needing attention including enlarging the target group to include those marginalized groups such as women and children.

At the same time UNDP decided to end their support to the national agency implementing their aquaculture project – the LBDA – and indicated that the balance of the project budget could be used by FAO (with GOK approval) to provide some sort of "bridge" between the present state and the upcoming terminal phase of the BSF project, at the same time providing some continuity for those activities previously supported by the UNDP. It was hoped that the Implementation (terminal) Phase of the BSF project would start during the third quarter of this year.

CURRENT STATUS

I am tremendously impressed with the conclusions for the Implementation Phase of the Project itself. A lot of progress has been made in the past 16 years, but I agree with the conclusions [of the 1995 Technical Review Mission, the 1999 Tripartite Technical Evaluation Mission and with the draft Formulation Framework] that there is a great degree of farmer dependence on external assistance, and that the project is not yet at a point where sustainability and continued expansion could be expected. The terminal phase of this Project represents a major change in both direction and attitude. While it represents an exit strategy for the BSF, something I have rarely seen with aquaculture development projects (usually funding is simply not renewed), I sincerely believe that many of the goals are achievable, and in my opinion the most important goal – farmer self-sufficiency and independence – has a high chance of success. A great debt of gratitude is due to the BSF who have steadily supported the cause of aquaculture development in western Kenya for what will be nearly 20 years at the end of this project.

Farmer dependence.

In 1986 I saw many farmers that were totally dependent on the government. Their ponds were initially sited and surveyed by LBDA or DOF personnel. Construction was supervised by the government and in many cases the ponds were built with fund received from a government-supported loan (actually grant) program. Many groups were in fact first formed to capitalize on this program. The fish seed (tilapia only at that time) were produced at government FPC's and were brought to them by the government agent, who returned at intervals to advise on management. At some point the agent returned with a net to assist with the harvest, and the cycle was repeated. It was felt by many that if you do this often enough, farmers would "catch on"; if fish farming didn't spread on its own, you simply needed more inputs for a longer time.

Unfortunately, much has not changed in the past 14 years. On this trip I saw some of the worst examples of farmer dependence that I have seen anywhere in Africa. One farmer had not harvested his pond in the past three years, and was pleading for a loan (he had actually received one several years ago from the LBDA which he did not repay) so he could turn his pond into a "money-maker". When we tried to explain that if he harvested his pond now, he could sell some fish, and with the money buy new seed, both tilapia and clarias, and some feed for the next cycle. If he fed that feed for the next four or five months, he would be able to harvest again, only this time his cash sales would be even greater. From this harvest he could probably afford to build another pond. The farmer rejected all of this, insisting that a loan was the only way.

Another farmer who had not harvested his pond for an extended period was waiting for the agent to set a date and bring the net so he could harvest. The farmer called the pond "his" (the agent's) project. Waiting on the government for either a net to harvest or seed for stocking has become almost a way of life for many small farmers accustomed to government direction and support.

Probably the classic case was a group pond that had been in operation for several years. The water was clear, water was flowing through the pond, and there was no sign of anything in the crib (a.k.a. "magic fence[*****]"). I asked the group leader why he didn't put any manure in the compost, and he replied that he was waiting for the agent to come back and "show him how" to do it again. I agree that some things in aquaculture are a bit tricky and take a bit of study, but dropping cow manure in a crib is not one of them.

[*****] I have come to call the crib (the stakes surrounding the compost) a "magic fence" because so many farmers apparently think that putting that ring of stakes in the pond, sometimes elaborately woven into a mesh wall, will in itself magically grow fish. I say this because you see so many ponds with a completely empty crib.

In many ways we have built dependency into the project. We have done this unintentionally most likely, but we have done it nonetheless. To help farmers get "quality seed" we have discouraged private hatcheries and build a series of government FPC's. To help the disadvantaged farmers, we encouraged them to form "self-help" groups, then gave them money to get started (I guess I really don't understand the meaning of "self-help"). We want them to learn how to do it right, so we make a huge effort to try to visit each pond individually, to advise on management, and to even help them with the harvest. The result generally is not farmers who successfully adapt the technology, but farmers who consider the pond to be "our" project, and who grudgingly follow our advice or admonitions. This usually means fairly basic management, a compost with little in it, water flushing through the pond, and a pond full of eight or ten months' worth of reproduction. We feel like we are pulling teeth to get them to do what is in their own best interest all along.

None of this is really a reflection on the effort that has gone into teaching farmers about aquaculture. There has been a tremendous effort by scores of dedicated staff over the history of the project. The problem is that this approach to aquaculture development just doesn't work, and I do think it's safe to say that more of the same can't be expected to produce any major changes in trends. Many of these farmers simply "cycle through" the program, with abandoned ponds replaced by new ponds in the survey sheets. If the staff is increased in an area, you would expect a slight surge in new construction and active ponds; with cuts there is major slippage of the program. What we need is less "technical assistance", where we repeatedly visit farmers and tell them what to do, thereby training them to wait for us for instructions. We need to shift to "extension education", where the emphasis is on really transferring an understanding of the principles and practices of aquaculture, so the farmers can make their own decisions on a daily basis.

Advanced Fish Farmers.

When I was here in 1986 I didn't see anyone that I considered to be a "model" farmer, someone with several ponds who was practicing good management, harvesting on a regular schedule, and re-stocking with his own fingerlings. Not only did I see some of these individuals in every HCA I visited (and outside the HCA'a as well), several of them had been trained in clarias spawning by the LBDA, and they were spawning these fish and selling fingerlings as well. Granted, in all cases, the survival from fry to fingerling stage was low, but they had the facilities, interest, and skill to do this on their own. This was amazing to me.

Before this trip to western Kenya, I was very pessimistic about the near-term potential for clarias in African aquaculture. My basic advice to farmers (as recently as six months ago) was if you can manage to get a few fingerlings from someplace, toss them in your pond. But do not count on clarias, and don't expect them to be a big part of your future because the source of fingerlings is unreliable.

Well, much of this is still true, but the farmers here have shown that technology doesn't stop at the LBDA FPC property line. In addition to spawning clarias, many have developed regular sources of supplemental feed, and some even act as small-scale feed distributors to their neighboring farmers, buying rice bran in lorry-loads, and retailing a bag at a time. They also are seeing aquaculture as a real income-generating activity, and are harvesting their ponds on a regular basis, restocking their own seed and selling extra seed to neighboring farmers, who have in many cases joined together because of a common interest, not just to get a government grant. These farmers are called "Advanced Fish Farmers" (AFF's), and many of those that I saw truly are advanced.

Everyone wants to help the poorest of the poor. If you could come up with a scheme to turn the landless poor into fish farmers you could probably find a donor somewhere to fund the project. This project talks of the marginalized farmers as being a target, and that is noble, but experience has shown that it is impossible to reach thousands of these one-pond farmers directly. That is basically what the project has been doing here for sixteen years, and all of these farmers are still totally dependent for nearly everything. We can, however, effect a fundamental change in their situation. Instead of having them dependent on the government for fingerlings, equipment and advice, and be doomed to disappointment and failure, they can rely instead on the advanced fish farmers and their associations.

Unlike a government FPC, where fingerling orders are sometimes considered a big inconvenience, an AFF has a vested interest in selling seed – that is his income, and his customers are his friends, relatives and neighbors. I always like to say that the biggest difference between a government hatchery and a private hatchery is that the primary concern of the government manager is his budget[†††††], the primary concern of the private manager is his sales. Once the AFF's are not only allowed to sell seed to their neighbors, but are actually encouraged to do so and are given the technical training to do so efficiently, liberation begins.

[†††††] The cost-benefit analysis done during the preparatory phase of the project determined the cost-benefit ratios of the LBDA FPC's ranged from a low of 1% (Lugari FPC) to a high of 9% (Chwele FPC). This means that for every KSh100 spent at the facility, there were total sales of between KSh 1 and KSh 9. These figures are probably even somewhat biased toward the facility.

Without much fanfare, the AFF's have already largely taken over this role with respect to tilapia seed. One fish association I visited with even made a trip to Lake Victoria for tilapia broodstock to replace what they felt was inferior LBDA stock. As soon as they began to spawn, they were distributed within the association. I am not saying that this was entirely necessary (see APPENDIX 7, QUALITY SEED), but just imagine if this type of independent action and cooperation is encouraged and promoted, which is exactly the main point of the terminal phase of the project.

These AFF's can (and in many cases already have) taken over other roles of the government as well. We list "demonstration" as one of the purposes of government or other institutional (i.e. school) ponds. The reality is that these are rarely good demonstrations for a variety of reasons. Even if we manage to get a good harvest from a "demonstration" pond, the results aren't believed by most of the farmers. However, the AFF's <u>by definition</u> are good demonstrations (they are classified based on their management, not just the number of ponds they have), and most are quite willing to share the knowledge with their neighbors, especially since they are customers for his fingerlings. That is what you call "servicing what you sell".

One goal of the Terminal Phase of the Project is to have one AFF in each HCA, selling fingerlings and providing a resource and an example to their neighbors. To really assure the security of the marginalized and other one-pond farmers, they need to have access to <u>more than one AFF</u> in the area. This not only gives them an option if they have any problems with a fingerling producer (not every AFF will be totally honest), but (God forbid) if the only AFF in an area should die, the whole area may also if everyone is depending on him for seed, demonstrations, and advice. I would suggest revising the project goal upward to three AFF's in or near each HCA.

Accepting the decision that private fish farmers can assume many of the government's responsibilities is a big step, and will require a big change in thinking here. With the exception of a few side trips into the private sector, I have been a lifelong public servant. I know that we have come to accept that a lot of things should be done by the government, but that thinking needs to change, if for no other reason than the budgets in the future will simply not be large enough to continue.

<u>Privatizing seed production</u>.

The privatization of both tilapia and clarias seed production is the cornerstone of the project. It's a pretty basic concept that if fingerlings are not available, farmers will not harvest their ponds, much less invest in new pond construction. It is conceded that the old system of LBDA and DOF FPC's does not work well, and that the private sector is capable of taking over that mission. According to the reports and plans I received, there are only two LBDA FPC's still in operation (Alupe and Chwele), and these will only be operated temporarily[‡‡‡‡‡]. Eventually all of the existing FPC's will be turned over to the private sector, to either individuals or to groups, and all of the seed production will be in private hands.

Well, that is easier said than done. <u>It will be very difficult for the GOK to totally free itself of the burden of these stations</u>, even if they will serve no significant purpose in the very near future. It will take a specific commitment, with a clearly stated time frame for individual facilities (DOF as well as LBDA), and a determination to stick to it. As long as they remain open (whether for "emergency" seed, or for use as training centers), they will remain a drain on the DOF budget and will send a mixed signal to the fish farmers of Kenya. If we really intend to put the farmers in a position where they will be self-reliant, we need to commit to the process.

As hard as closing the facilities will be, actually transferring them to private ownership may take a miracle. Should these facilities be transferred to individuals or to groups? Should they be sold (and for how much, or to the highest bidder?) or given away? Can the GOK really "walk away" or will they be transferred with strings attached? Should they be transferred to someone who has demonstrated management ability, such as an AFF or one of the current FPC staff, or should we let political influence carry the day? Do we want them to be productive, or do we want to use them to uplift a disadvantaged group? Once you actually get ready to turn one over there will be numerous questions raised and roadblocks thrown up by a lot of people. I have my own preferences, none of which will really matter. I do recommend that the DOF be in a position to make those decisions when the project formally begins later this year. If the procedure has already been determined by the GOK, excellent. If it will require a committee's recommendation, set up the committee now and give them their charge. If it will require an act of Parliament, better get started.

Regardless of the status of privatization of GOK facilities, the development of the private sector seed production capacity is and should be a top priority. On-farm trainings on the topics of clarias spawning and fry survival,

[‡‡‡‡‡] In my final meeting, the DOF expressed an interest in keeping the Chwele FPC open. By the cost-benefit analysis, this was the most efficient of the LBDA FPC's, and would be the best choice. However, I would suggest at least an annual reassessment of this decision. If the project really works as planned, within a year or two it may be evident that even one public-sector FPC is no longer necessary.

tilapia seed production, and intensive pond management all are priorities. There are farmers in place now ready to spawn clarias, and they are already waiting for the technicians to arrive and train them. While spawning *per se* will not be difficult (see APPENDIX 9, CLARIAS SPAWNING), poor fry survival is a major problem and will require a very specialized training of managers. However, applying known technology to this problem (see APPENDIX 10, CLARIAS FRY SURVIVAL) can produce some very dramatic results and will provide "instant credibility" to the program and the technicians involved.

Organizational framework.

In the past, there has been fragmentation of the Government units responsible for aquaculture development in Kenya, including the LBDA, the Department of Fisheries and the Ministry of Agriculture. To rectify this situation, since July, 1999, the DOF, the Agriculture Department and LBDA have been brought together under the same umbrella, the Ministry of Agriculture and Rural Development (MOARD). Along with the reorganization it was determined that if something was a "core Function" of an agency, that responsibility should not be duplicated by another agency. Since aquaculture is a core function of the DOF, they will co-ordinate the implementation of this project for the MOARD, drawing personnel resources from the LBDA and MOARD as necessary. The Nation Project Coordinator will be provided by the DOF and the Project Headquarters will be located in the DOF offices in Kisumu.

I was very impressed with personnel at all levels of the DOF that I met on this trip. The DOF definitely has the historical perspective on aquaculture necessary to appreciate the importance of this radical change in approach. I believe that the DOF leadership is sincere in their desire for this project to succeed, and will provide the best field staff at their disposal to see that it happens. I believe the field staff will perform very well under this new program direction, especially if it is seen that the most competent individuals are put in responsible positions and that hard work and dedication is rewarded.

As the project itself winds down, the number of staff earmarked for aquaculture will decrease, and those remaining will have increased responsibilities that will require greater technical and communication skills. After the Project ends, there may only be one Aquaculture Specialist per province. These individuals need to be carefully selected based on their demonstrated performance on the Project. Their new roles may require some continuing education in specialized areas.

As the role of government decreases, and the farmers actually become independent, the GOK could have a "panic attack". After decades of being totally in control, it will be difficult for many to accept the new order. For the "good" of the farmers, or the consumers, or the environment, or something or somebody, there will be an urge to increase regulation and control of this budding industry. This should be resisted by any means possible. Rather than actually having the intended result of assuring quality fingerlings for farmers, or healthy fish for consumers, or pollution-free discharge to the environment, or whatever else may be intended, the actual result may likely be an opportunity for some civil servant to exert undue influence over individual farmers.

Technical Materials.

If there is much good technical aquaculture information written for either the private farmers or the FFE's it is not widely available. This has been recognized in the project plan and the production of quality technical information by the IEC Officers is a priority. The credibility of the individuals and the Project as a whole, and certainly the ultimate success of the farmers, will depend largely on the accuracy, availability and applicability of the information produced. There is currently a lot of information and recommendations out there that are simply wrong, and this needs to be corrected.

As we move into this next level of aquaculture, the type of information needed by farmers will become much more technical. It will no longer be enough to tell a clarias seed producer to fertilize his fry pond until it "turns green"; he will have to know different types of zooplankton, which are needed, at what time in the cycle, at what densities, and how to grow them. It will therefore be necessary for a farmer to have the tools (plankton net and at least a low-power magnifier) to actually see what he is doing.

Fortunately, it is becoming much easier to produce information locally (not necessarily good information, though). With digital cameras, desktop publishing software, and color laser printers, a talented individual will be able to produce very professional material from Kakamega, or wherever the computer is located. Also with the internet, an IEC Officer in western Kenya can be in near-instant communication with resources all over the world. This will greatly facilitate the editing and proofing of any materials produced, which I highly recommend.

Sometimes simple is better. A whole series of one- or two-page "Fact Sheets", each covering a fairly specific topic, can be produced over time. They can be distributed to the industry as they come out (through e-mail to those that have it), and collected by the users in a notebook. Each of these Fact Sheets (or a couple of related ones) could serve as the technical basis for specific Project Staff, AFF, and/or group trainings. While at Sagana Fish Station I was given copies of several such handouts that were produced there. The format of these was excellent: they were limited to a fairly specific topic; they were easy to read, with information in "bullet" format; they contained fairly specific information.

I would suggest that publications aimed directly at the fish farming industry be issued from the Extension Service[§§§§§]. This branch of the Department should be in the best position to evaluate which publications are necessary, what information is appropriate for the industry, and what level of detail they should contain. These will probably be written by an aquaculture supervisor or the IEC officer[******], but in some cases the author of a specific paper may be a specialist not even in the Extension Service, but a scientist, facility manager or university professor that has the greatest knowledge and/or experience in a given area. However, even in these cases, the publication should go through the Extension Service review process and be "published" by the Extension Service.

At the risk of slowing down the publication process, a rigorous review of extension materials should be performed. All of the materials I have seen here contain at least some of what I would consider to be factual errors or inappropriate recommendations. Nobody is right all of the time (myself included), which is why every publication should be reviewed by a cross-section of DOF staff and AFF's before publication. Reviewers should not be afraid to question statements or pertinence of anything in the draft stage. Not everyone is a good reviewer, and the IECO will quickly learn who is capable of performing a useful review. The worst reviews I get are the ones with no corrections and a "good paper" comment on them – this does not improve the quality of a paper. Not every question raised in a review will result in a change – but we shouldn't be afraid to question any "sacred cows" of aquaculture or to ask the source (and verification) of any particular information or statements.

It is essential that the information and advice we offer the farmers is accurate. I will give an example of some current technical recommendations, based upon what I believe to be inaccurate information, which has a profound (negative) effect on the profitability of the industry. I will stick my neck way out on this, but what the heck!

Fish Marketing.

People in the Lake Victoria basin are accustomed to big tilapia. Tilapia from the Lake weighing several kilograms are not that unusual, and there is actually a 250 gram (approximately) minimum size limit imposed on the Lake fishermen. Tilapia have numerous small bones, so the bigger the fish, the easier it is to separate meat from bone, and this is especially important for small children. Many people, if they have the money, will buy a bigger fish for these reasons. If you talk to farmers and GOK staff just about anywhere in western Kenya they will tell you there is a real "consumer preference" for larger fish, and to get the "best price" they need to produce a table fish of at least 400-500 grams. Fish approaching 1 kilogram are the real gold, fetching by far the best prices. While smaller fish, in the 100-250 gram range can usually all be sold at the pond bank, they are often sold at "give away" prices.

To produce these larger fish, a longer growing period is obviously required, and the LBDA generally recommends (I base this not on their written recommendations, which I haven't seen, but on what farmers working with their program say their harvest cycle should be) a production period of 8-10 months. The problem with tilapia is that they begin to breed at 4-5 months old, and the reproduction interferes with the growth of the original stock. To reduce this problem, clarias are also stocked in the ponds.

Another solution that has been proposed and promoted is the culture of all-male tilapia. By stocking only male fingerlings, you can basically grow them forever without reproduction, and produce a crop comprised of only high-value large table fish. Males can be selected from mixed-sex fingerlings by a trained person; alternatively, tilapia fry can be fed a hormone for a short period which will result in the production of all males once they mature.

I'll bet that 90% of the people who have read these last few paragraphs have been nodding their heads - yup, yup, that's exactly right! Well, none of this is right, because it's based on faulty data, and it is costing most farmers at least 50% of their potential profits. That's a big statement but here goes.

Big fish sell for more than little fish. That doesn't mean that they are "preferred" by the consumers. Just because a cow sells for more than a chicken, doesn't mean that Kenyans prefer beef to poultry. The confusion comes in our case from the fact that nearly all fish in Kenya are sold "by the fish", not by the kilogram. When a pond is harvested the larger fish (in the 500-1000 gram range) may sell for as much as KSh 150 each, while

[§§§§§] Manuscripts intended for submission to scientific journals or other outlets should go through the normal channels for such publications. These may later be modified and re-published for Extension Service release if appropriate.

[******] Under the "new" Extension Service, specialists way be required to produce newsletter articles or extension materials. However, standards for all of these materials should be high – in many cases the ability to write well does not correlate with rank, seniority or title.

those in the 100-250 grams size range may only fetch KSh 10-15 each[††††††]. The higher value and preference for the larger fish is obvious, or is it?

On the next page (Table 1), I summarized data presented in the Marketing Study, and performed an additional calculation as well. To summarize the data I averaged the "pond site" market prices for tilapia and clarias in each of the three size ranges given for the twelve study sites in western Kenya visited during the PRA/Marketing study (since clarias is not raised everywhere, data were averaged for those sites given). The prices were given in the report for the size ranges of 100-250 grams, 250-500 grams, and 500-1000 grams. In order to calculate a "price per kilogram" I used the mid-weight of these three ranges; 175 grams, 375 grams, and 750 grams, respectively.

<u>The main point to be made from this data is that while fish are sold "by the each", and large fish sell for more individually than small fish, the actual value of the smaller fish is much greater. The small tilapia, sold at supposedly "give away prices" are worth KSh 83.4/kg, the medium fish are worth KSh 71.2/kg, and the large "Premium Price" fish are only worth KSh 66.7/kg</u>[‡‡‡‡‡‡]. Couple this with the fact that a crop of 100-250 gram tilapia can easily be raised in four months, and by stocking more fingerlings the same total yield (in kg/ha) can be achieved as with the ten-month culture period, the "actual facts" show that the average farmer could double or triple his money by growing a crop of smaller fish every four months, even considering the extra fingerling costs.

This example was probably much too long-winded, but it is the basis of our technical recommendations to the industry. I believe that it is quite important. Our challenge clearly is to rise above pride, emotion, gut feelings, and appearances, and to present clear economic data to the farmers upon which they can base the management of their aquaculture business.

All that aside, marketing in the traditional sense has not, and probably never will be, a problem with pond-raised fish in Kenya. The population density is so high, and the demand for fish so great, that it is unlikely that efforts beyond present pond-bank sales will ever be necessary. Farmers may opt for other alternatives, such as wholesaling a pond of fish to a middleman, for the sake of convenience, but it is unlikely that with the current pond areas the volume of fish produced will ever exceed the ability to sell them on the spot.

Farmers may well work on consumer education to increase demand for clarias or for smaller tilapia, and coordinate harvests with other farmers to avoid short-term supply gluts, but major changes in marketing channels will not be required. In an extreme case of short-term over-supply of fish (which would really be great), the only infrastructure necessary would be a 48-quart Igloo cooler with some ice to hold the fish overnight, or for transport to a more urban center.

<u>Feed cost and availability</u>.

Feed cost and availability has been identified as a serious constraint to both intensifying production in existing ponds and expanding the industry in the future. While reasonable production can be achieved with manure-based systems, to really capitalize on the potential of aquaculture feeding is necessary.

Rice bran is the basis of the supplemental feeding at this time, with dried fish (omena) and dried fresh-water shrimp sometimes used to increase the protein. In some cases farmers are already buying in lorry-loads, and retailing 70 kg bags to individual farmers. This type of cooperation should definitely be encouraged, and expanded to other areas when possible through associations and/or AFF's. There are larger companies involved in manufacturing specialized animals feeds for the dairy and poultry industries. Although it is cost-prohibited at this time, apparently even fish food pellets are available in Nairobi. If blended or pelleted feeds become or are shown to be cost-effective, these channels will probably become the major ones for manufacture and distribution.

[††††††] This is actually the extreme price ranges reported pond-raised tilapia in western Kenya on page 19, Marketing Study on Sustainable Small Scale Fish Farming Enterprises in LBDA/BSF/FAO Project Areas GCP/KEN/060/BEL, by Major Step Consultants, Kisumu.

[‡‡‡‡‡‡] It may be that small fish actually costing more per kg than larger fish is an "artifact" of selling fish "by the fish". A buyer wanting a fish for dinner can buy one small fish for KSh 15, while a bigger one, which he may really prefer, would cost KSh 50, out of his price range. The small one cost KSh 84/kg, and the big one only KSh 67/kg, but he only had to spend KSh 15 to have one small fish for dinner. That is why when we buy a single piece of fruit in the supermarket (at least in some supermarkets) it costs more per kg than if we buy a whole bag of them – it's called "discount pricing". If a buyer was faced with the real facts (what we call "unit pricing, or price/kg for everything he/she buys), this probably would change. Faced with three piles of fish (small, medium and large fish), all weighing exactly one kg, it is doubtful that the average Kenyan consumer would pay more for the smaller fish – but that is exactly what they are now doing.

There has been some fairly specific information presented with respect to food conversions and profit margins with feeding various compounded feeds[§§§§§§]. I don't mean to question this data as it would be quite valuable to farmers contemplating supplemental feeding. However, determining food conversion efficiency is a bit tricky when dealing with planktivorous fish such as tilapia (and even clarias). The original source of this data[*******] should be located and evaluated by the project management.

Mixed plankton is quite high in protein. When you start a feeding program for filter-feeding fish all you have to add is energy (carbohydrate such as rice bran) to see some pretty significant increases in growth and production. Once you increase feed to the point that the overall protein level of the diet is inadequate, increased feeding of rice bran alone will less efficient. To maintain efficiency at higher feeding rates, you will have to increase the protein in the total diet somewhat. You can either do this by adding a high-priced protein source to the rice bran, or increase the bloom. Since manure is cheaper than omena, and most ponds I saw did not have really good blooms, I think I would opt for this strategy first. Some research has already been conducted on this subject in Kenya[†††††††]. This may be a good area for continued research in the future.

My opinion is that greater immediate gains might be made through improvement in product form or feeding methods than through formulation. Rice bran is eagerly consumed by both tilapia and clarias, but probably a small percentage of that fed actually goes down a throat; much spreads out to the pond to act as a high-cost organic fertilizer. While I am not necessarily suggesting a manufactured rice bran pellet, developing alternative feed forms or feeding strategies (such as a "feeding ring" to contain the rice bran presented to the fish; forming rice bran "clumps" with animal blood; cooking rice bran to make an ugali-like consistency that the fish can pick at) that will result in more food consumed directly would probably provide a more cost effective action than adding high-cost protein to the diet.

The whole dried omena and shrimp by themselves would be a great high-protein supplement for clarias broodstock in preparation for the spawning season. They eagerly search for and consume these when fed whole along with rice bran. These dried fish and shrimp, when finely-ground, would be great "starter diets" for clarias fry for the first week or two, when greater proportions of rice bran can be mixed in. Since clarias fingerlings may sell for KSh 1000/kg (a 2-gram fingerling selling for KSh 2), the cost of feed is almost insignificant.

<u>Recommended technologies</u>.

In general the technology being promoted and used is appropriate: mixed-sex culture of tilapia; polyculture with clarias when seed is available; heavy fertilization with organic manures; feeding with rice bran. In the appendices I discuss at length some of these practices and some ways that I feel may improve profitability. My basic philosophy is K.I.S.S. (keep it simple, stupid – no offense intended). Simplicity is the key to success. Don't use a pump is you can use gravity flow; don't use hormones if you can stimulate natural spawning; don't strip fish if they can spawn themselves; don't use monosex culture if you can grow fish to market size through mixed-sex culture. Just because we <u>can</u> do something, doesn't mean that we necessarily <u>should</u>.

One thing that I would focus some more attention on is the maintenance of good blooms. If manures are lacking, use inorganic fertilizer. The second thing to be addressed is the long harvest cycles, and the fallow period between crops. Producing smaller fish in a shorter time period (more harvests per year), and refilling ponds and putting them back into production immediately, will have a major impact on profitability.

<u>Groups and Associations</u>.

The formation, development and use of groups, co-operatives and associations is such an important part of the Project plan that I want to repeat some definitions as I will use them in this report.

Group. This is defined as a number of individuals who have come together for the purpose of fish farming, and they jointly own a fish pond or fish ponds.

[§§§§§§] Pp 42-47 in the Marketing Study on Sustainable Small Scale Fish Farm Enterprises in LBDA/BSF/FAO Project Areas GCP/KEN/060/BEL.

[*******] FAO. 1987. Feed and feeding of fish and shrimp: a manual on the preparation and presentation of compounded feeds for shrimp and fish in aquaculture. FAO, Rome. Micheal Bew (FAO and UNEP) pp 275.

[†††††††] Wilson Maina Gichuri, Fisheries Officer I at the Sagana Fish Farm, has completed a MS Degree on the economics of feeding and fertilizing tilapia ponds. This and other similar original research should be located and evaluated.

Association. This is defined as a conglomeration of individual farmers and/or fish farming groups joined for the purpose of more effective coordination of activities, and for established capacities to address several constraints and limitations faced by members. They are primarily social organizations. Members of an association do not own joint fish ponds under the umbrella of the association. Members of an association are drawn by a common interest in fish farming, and are registered under the Ministry of Social Services. An individual can join as many associations as he/she wishes.

Co-operative Society. Farmers' co-operatives are primarily established for the purpose of providing credit to farmers, accessing inputs, and establishing marketing networks. Co-operatives play a major role in the marketing of fish from Lake Victoria itself, but may not play that major a role with aquaculture. Co-operative societies are registered under the Commissioner of Co-operatives and are generally business oriented, declaring dividends based on share holdings by each member. Unlike associations, law allows no member of one registered co-operative society to join any other co-operative society.

It is unlikely that group ponds will ever make a significant contribution to the total pond fish production of western Kenya. Pardon my cynicism, but most groups in Kenya were formed not from a desire to join together on a fish production project, but to join together to get a loan or something else substantial from the government. Since this project will thankfully not be offering money to anyone, and I hope that they make that <u>absolutely clear</u> at the onset of the project, I doubt that there will be a flurry of group ponds being built in the next four years.

That aside, I did see a few group ponds that had potential. Although management of these ponds under the former extension approach was pretty dismal (everyone just kept waiting for the agent to come by and advise them on "his" project), participation by these groups or representatives of the group in various on-farm training programs will be both open and encouraged. This will allow the agents to work with a large number of individuals that really <u>are</u> interested in learning aquaculture, without wasting their time on repeated visits to individual ponds with little visible improvement in management.

Functional groupings of fish farmers is a different matter altogether. They can serve some tremendously valuable purposes, and may be critical to the expansion of aquaculture in the long-term (after the next four years). Before I get to their role here I would like to give two examples (neither from Kenya) of how groups "saved" fish farming. In the first case, a crooked civil servant decided that if some individual fish farmers didn't bribe him, their ponds would be declared "health hazards". The area fish farmers joined together in an association, discussed the problem, and went as a group to the DC. The problem ended immediately. It is doubtful that any one fish farmer acting alone could have done this.

In the second case, farmers were discouraged from working hard on pond management because of their extended family obligations. At harvest everyone claiming any kinship came to the pond asking for "their" fish. The farmers wanted to fulfill their family obligations, but they also wanted to show a little profit on the deal. So the association came to the rescue. On harvest day the owner stayed at his house with instructions to the other association members as to how many kg of fish they wanted. At the start of the harvest, which was conducted by the other members, those fish were sent to the owner and the rest of the crop was sold at the pond by the association. Family members (of the owner) coming to the pond and begging for fish were told to go to the house for their free fish, or they could buy whatever they wanted at the pond for cash. At the house, the farmer expressed sympathy, but displayed the pile of fish he had available for his entire extended family, and offered one or two fish to each. Everybody got some fish, and the farmer got a profit for his labors. He reciprocated the effort at the next harvest.

These two anecdotes are perhaps a little off the mark as to the main purpose for an association but they do serve to illustrate how farmers joining together for the right reasons can be very beneficial for everyone, if <u>they</u> see the need and <u>decide to do it for their own reasons</u>. I feel very strongly that we (the government) should never go into an area and tell the farmers they should form an association. This is more of the same failed approach of us telling them what to do, and it won't work any better.

I saw some powerful examples of farmers helping farmers in (Lurambi Division), and I am sure there are functional associations in place elsewhere. These should be supported both because they represent active fish farmers who are trying to get ahead, and also because working with these associations will speed the transfer of technology to and throughout the industry. Farmers associated for no other reason than to facilitate the distribution of seed among the members, or to allow retail users of feed to purchase at wholesale prices, will serve as a functional entry point for the program to the community, especially if the association contains at least one AFF.

CONCLUSIONS AND RECOMMENDATIONS

The Project Plan is sound, should achieve the most important goals, and should be started as soon as feasibly possible.

Designation of the DOF as the implement agency for this project was a good decision. They have aquaculture as a statutory core function, they have a large number of trained staff from which to select the personnel needed for this project, and at every level I felt a true interest and commitment to the success of the project. Following are some of the immediate actions that could be taken by the DOF prior to the formal start of the Project.

> Generate a mailing list of AFF's, groups/associations, and NGO's that will be or potentially could be involved in the project.
>
> Issue a letter from the DOF or MOARD to everyone on the list informing them of the upcoming project, the goals of the project, and both what will and will not be done (such as provision of loans or equipment) under the project.
>
> Assemble copies of all available technical information available in western Kenya. The bulk of this may now be in the hands of the LBDA, which until last year was the implementing agency for the Project. This should include handouts and posters developed for farmers, as well as more technical resources and training outlines intended for government staff. Assembling this information will probably take several months; doing it now will save a great deal of time when the IECO's for the Terminal Phase are on board. Reviewing existing information will be a first step to the production of new information.
>
> Tentatively select staff that will be involved in the project. I realize that commitments cannot be made until the project is official, but the DOF should be in a position to move quickly on this when necessary.
>
> Locate in-country sources of "mosquito" seines, microscopes, stereo dissecting scopes, and affordable hand lenses. One person could be detailed for one day each in Nairobi, Kisumu, Kisii and Kakamega to search the market local for availability of these items, location of vendors, and costs.
>
> Identify the most experienced technical staff with expertise in clarias spawning. Discuss current LBDA procedures, suggestions given here in appendices, and other advice available from FAO, and implement trials of new procedures for increasing fry survival ASAP on all government FPC's still operating. If fry survival increases significantly, begin extending technology to farmers, if only by invitation of any interested AFF's to assist with on-going spawning on the FPC's. We do not really need to wait for anything/anyone before we help existing farmers with existing personnel.

There should be no give-aways to fish farmers, even with other MOARD programs for which ponds are eligib

Technical materials developed for this last phase must be accurate, appropriate, sound, and produced in large enough quantities to be readily available to anyone that wants them. The first step will be a review of materials currently being used or on file.

Many of the "Advanced Fish Farmers" I met really were technically advanced, some to the point of successfully hormone spawning clarias on their farms. The identification and further technical development of these farmers will be critical to the main goal of farmer independence. Many are already community leaders acting as fry production centers, feed wholesalers, demonstration farms, and unpaid extension agents. These roles should be developed and strengthened through advanced technical training conducted on their farms, both for them and for their less-advanced neighbors. The DOF should resist the urge to regulate these farmers in their role as FPC's; rather they should be trained to increase both their seed volume and quality. The first immediate need is for advanced training of AFF's in clarias fry survival. Subsequent/concurrent trainings will address tilapia seed production methods (as more people practice polyculture, there will be fewer tilapia fingerlings available), and economic intensification of production. Those AFF's who are the first to realize (or already have) that their expanded service to the community will ultimately pay off in increased fingerling sales will be the first recipients of on-farm training, and the first to benefit from the intervention. Those acting as feed wholesalers should be further developed, perhaps through the assistance of NGO's.

As the role of government decreases, and the farmers actually become independent, the GOK could have a "panic attack". After decades of being totally in control, it will be difficult for many to accept the new order. For the "good" of the farmers, or the consumers, or the environment, or something or somebody, there will be an urge to increase regulation and control of this budding industry. This should be resisted by any means possible. Rather than actually having the intended result of assuring quality fingerlings for farmers, or healthy fish for consumers, or pollution-free discharge to the environment, or whatever else may be intended, the actual result may likely be an opportunity for some civil servant to exert undue influence over individual farmers.

If residual funds can be redirected, initial AFF trainings in clarias spawning/fry survival could begin well before the project as a whole is officially started.

Research and demonstrations (both on-farm and off-farm) can be most helpful to the industry if done properly and if the research/demonstration addresses questions of interest to our customers. The initial request for the information to be developed should come from the farmers themselves. On-farm trials should be coordinated through the extension service. Both the DOF Sagana Fish Station and KMFRI could play valuable research support roles.

The focus of the technical packages extended to the industry should be on basic, proven, economic management practices. Simplicity is the key - integration doesn't mean the chicken house must be physically over the pond.

The major theme of the Project "sales pitch" should be economic intensification and self-reliance.

The concept of HCA's is sound. The failure of many programs has been dilution of efforts. However, if there is not at least one AFF (and preferable two or three) in an HCA there should be adjustments immediately. This plan will not work if there are not already AFF's in place.

The government FPC's should be closed within a year. The planned transfer of these facilities to private ownership may be extremely complicated, and therefore the development of a plan should begin now. It would be ideal if these stations ended up in private ownership by an AFF (or someone who could turn into one after taking possession) who could operate them as efficient FPC's, but this is not essential to the success of the project – it would just provide for one more resource for the industry. In any case, the government should not maintain any financial obligation to these facilities after transfer, even (or perhaps especially) if they are transferred to a group of marginalized farmers rather than to an individual. I would rather consider transfer to a current or former employee of the facility who could operate it successfully and make a good business from it.

The plan to use groups and associations to reach out to the marginalized farmers is sound, and should be effective. Realize that most of these individuals are now extremely dependent and will continue to be dependent. We are merely shifting their dependence to someone (an AFF in their village) who has a greater chance of meeting their long-term needs for continued assistance than does the government. Everyone needs to accept early on that membership in anything is not a pipeline to a free lunch, just knowledge that can set them free. Let farmers themselves determine how they will or should be organized.

Note: The anticipated funding for a final phase of the project never materialised – this ultimate cessation of support taking effect slowly while activities at field level gradually atrophied.

Appendix VI: *Review of Aquaculture Extension in the Africa Region*‡‡‡‡‡‡‡

This document reviews the principles and methods used, in particular in the African region, in agricultural extension and aquaculture extension. It evaluates the different systems and assesses their sustainability. The document also comes with recommendations on how to change the extension services to make them more sustainable and effective in disseminating information to smallholder farmers.

The most important conclusions and recommendations are:

Although there have been quite some developments in the agriculture extension, most of the aquaculture extension programmes were based on the principle that it was necessary to introduce externally generated technology. This was caused by the fact that aquaculture is relatively new in Africa, but also by the fact that aquaculture projects were always executed by aquaculture technicians. The technicians focused on production increase only, and were prepared to manipulate local conditions if these were not favourable for the adoption of the advocated technology. The technology promoted by these projects proved not sustainable for most farmers.

Extension was in most cases simply interpreted as teaching farmers how to apply the developed technology. Only in the nineties some projects tried to really integrate aquaculture into the farming system, and new approaches for extension were used.

A real analysis of why aquaculture did not develop as hoped for was never made, and the question remains whether it can be developed under the present conditions. This question not only applies to aquaculture but also is relevant for rural development in a general sense.

Most successes in agriculture development are still only on a relatively small scale. This is largely because an enabling policy environment is missing in almost every African country. Extension and research operate within a national political and economic environment and have to ensure that the developed systems are adaptable for farmers who operate their enterprise within this environment.

Aquaculture should not be conceptualised as a purely technical activity. Instead, these local conditions need to be analysed and conclusions drawn as to the possibilities of aquaculture within those conditions. If aquaculture is to be integrated into farming systems one must also understand its interactions with the surrounding physical, socio-cultural and institutional environment. This analysis as well as the planning of improvements should involve farm families and rural communities.

This report concludes that in order to create sustainable development of aquaculture, a complete modification of the extension service is required. Presently the **objective** of extension should change to an improvement of the living standards through improvement of the overall farming activities. This requires an extension **approach** that is not specialised for certain crops, able to deal with agricultural problems, and able to take local possibilities, wishes and knowledge of farmers into consideration. This requires a much more participatory approach, and hence requires a change of the extension **system**.

The system requires **staff** who are willing to listen, and are able to assist farmers in analysing their situation and in making decisions on how to solve problems, and provide a service to farmers instead of following instructions from supervisors. Most of their work should be to respond to requests from the farming communities. Reacting to the requests of farmers opens good possibilities for the improvement of the linkage between extension and research and for conducting on farm research. It also opens the possibility to request contributions of the farmers to the extension service.

The financial requirements for such an extension service will vary between countries. It will however be more expensive in countries with poor infrastructure and with an unstable political and economic environment. The dilemma is that these countries are in most cases the poorer countries.

The process of developing good extension material takes a long time and requires expertise. Efforts should be made to develop standard sets of materials that have been properly tested for their effectiveness and that can easily be modified to the local situation. These basic sets can be developed for a whole region with comparable conditions.

Financial constraints may restrict changes in the extension service, but more than money; changes that effectively improve the extension services need people who are genuinely interested to learn the lessons from past failures. Hence, it needs professionals who are open for change who look beyond technologies only and who are focused on learning from farmers rather than teaching. This requirement is probably the most difficult to fulfil.

‡‡‡‡‡‡‡ This Appendix is a summary of the paper prepared by Henk van der Mheen as a background document for the 1999 Africa Regional Aquaculture Review (CIFA/OP24)

THE GENERAL AGRICULTURAL EXTENSION APPROACH	
Assumption of Problem.	Better technology and information exists, but is not available to the farmer. If communicated to the farmer, the production will increase.
Purpose.	Help the farmer increase his production.
Management.	Controlled by government, and decisions are usually made at national level.
Field staff.	Large in number.
Required resources.	High, and governments bearing the cost.
Implementation.	Through a large governmental field staff, no specific target group.
Evaluation.	Success is measured in terms of rate of adoption of introduced techniques.

THE COMMODITY SPECIALISED APPROACH	
Assumption of Problem.	The increase in production of a certain crop is realised through an approach that covers all aspects, including extension, credit, marketing, input supply etc.
Purpose.	Increased production of a certain crop.
Management.	Controlled by a commodity organisation.
Field staff.	Supplied by the organisation.
Required resources.	Supplied by the commodity organisation, which considers the crop a good investment.
Implementation.	The organisation often targets specific farmers and areas with high potential of adoption.
Evaluation.	Success is measured in the production increase of a certain crop.

THE TRAINING AND VISIT SYSTEM	
Assumption of Problem.	The extension staff is poorly trained, lacks supervision and logistical support, and has too little contact with the farmers.
Purpose.	Increased production of certain crops through more effective extension organisation.
Management.	Centrally controlled, with rigid planning.
Field staff.	Large in number.
Required resources.	Because of the large number of staff and the logistic support the costs are high.
Implementation.	Rigid pattern of visits and dissemination of standard packages.
Evaluation.	Success is measured in production increase, and in some cases in the number of extension visits and training.

THE FARMING SYSTEM APPROACH	
Assumption of Problem.	The external, modern technology does not fit the needs of the farmers. Suitable technology needs to be generated locally and take the whole farming system into account.
Purpose.	Provided extension staff with research results tailored to meet the needs and interests of local farming systems conditions.
Management.	Evolves slowly as results become available.
Field staff.	Highly specialised, and relatively expensive.
Required resources.	Carries out field trials in farmers fields and homes, that form the basis of extension message.
Implementation.	Research and extension staff together.
Evaluation.	Adoption of the technology developed by the Programme, and its continued use.

THE COST SHARING APPROACH	
Assumption of Problem.	Farmers not always interested in services extension provides, but which is more likely to fit the local situation and serve the people if part of the costs is paid locally.
Purpose.	Farmers acquire techniques to improve their agriculture enterprises.
Management.	Shared by various levels, responsive to local interests.
Field staff.	Locally recruited.
Required resources.	Limited.
Implementation.	
Evaluation.	Success is measured by farmers willingness and ability to provide some share of the cost.

THE EDUCATIONAL INSTITUTION APPROACH	
Assumption or Problem.	Agricultural colleges have technical knowledge relevant for rural people, but this information is not shared with the farmers.
Purpose.	To expose rural people to information on latest technologies.
Management.	Controlled by those who determine the curriculum of the education institutions.
Field staff.	Both extension and education staff.
Required resources.	Considerable, but since they are shared between education programmes and extension, the approach can be cost effective.
Implementation.	Through non-formal instruction in groups, to individuals, or through agricultural extension personnel.
Evaluation.	Attendance and extend of farmers' participation.

Table 1: Characteristics of various extension approaches

	Programme characteristics											
	Scope		Information		Goals		Message		Feed-back		Focus	
	National	Area	Out side	In side	Production	Consumption	Standardized	Flexible	Responsive	Not	Farming	Quality of Live
General Agricultural Extension Approach	**XX**			**XX**	**XX**		**XX**			**XX**	**XX**	
Commodity Specialised Approach		**XX**		**XX**	**XX**		**XX**			**XX**	**XX**	
Training and Visit Approach	**X**	**X**		**XX**	**XX**		**XX**			**XX**	**XX**	
Participatory Approach	**X**	**X**	**XX**	**X**	**X**	**X**		**XX**	**XX**		**X**	**XX**
Project Approach		**XX**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**XX**	**X**
Farming Systems Development Approach		**XX**	**XX**		**XX**			**XX**	**XX**		**XX**	
Cost Sharing Approach	**X**	**X**	**X**	**X**	**X**	**X**		**XX**	**XX**		**X**	**XX**
Education Institution Approach		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

X = applicable, **XX** = strongly applicable (after: Axinn, G.H. 1988)

	Institutional Extension	**Farmer to Farmer Extension**
Benefits	• Enables gathering of data • Easier to monitor effectiveness of technology transfer • Appropriate for high technology level	• Sustainable • Low cost • Rejection of the message is low • Wide coverage and depending on need and interest • Empowers farmers as they become responsible for their own destiny
Drawbacks	• Expensive • Coverage depends on resources • Message may be inappropriate • Centralised planning subject to rigid policies • Extension service can be influenced by politics • Dependent on personality and motivation of extension agent • Certain groups my be ignored • Not very stable, transfer of staff	• Higher rejection if external institution is involved in selection of motivator • Motivators might try to prevent other farmers from obtaining information • Loss of information of distortion of message • Loss of knowledge when not practised • Gender barrier
Suitable	• When introducing aquaculture • When introducing new aspects, techniques, information • When establishing links with other institutions	• When institutions are incapable of implementing extension • When knowledge already resides with farmers • When trying to increase the adoption rate

(After; van der Mheen, 1996)

Extension Requirements

From the previous chapters it follows that in order to create sustainable development of aquaculture, a complete modification of the extension service is required. Presently the **objective** of extension has been focussed too much on the production increase of a single commodity, in this case aquaculture. This should change into an improvement of the living standards through improvement of the overall farming activities. This requires an extension **approach** that is not specialized for certain crops, able to deal with agricultural problems, and able to take local possibilities, wishes and knowledge of farmers into consideration. This requires a much more participatory approach, and hence requires a change of the extension **system**.

Extension services are up to now characterised by a centralised hierarchical authority, specialised disciplinary departments and standardised procedures. Institutions that respond better to open learning environments and participatory methods must be decentralised, with multidisciplinary, flexible teams, and outputs responding to the demands of farmers (Pretty and Chambers 1994). This has profound implications. It needs a transformation of institutions and of learning approaches.

Management within extension services tends to be inward looking rather than directed toward servicing staff in the field, or providing necessary support, encouragement, or supervision. Field staff are typically not involved in the planning of resource allocation or policy priorities. They tend to be regarded solely as the executive arm of decision-makers located elsewhere or at a higher level. Priorities and financial allocations are thus handed down to the districts for implementation, however well or ill they suit the particular needs of farmers in the area. Such centralisation parallels the attempt to extend packages across the board, disregarding both geo-climatic and socio-economic variation within the locality. Under the present set up farmers themselves have no influence at all on how the extension service is operating. They are only seen as recipients.

An extension service that aims to deal with the problems of farmers will have to listen to farmers and requires an interactive system, whereby farmers inform the service what assistance is required and what information they need. Apart from a change in the approach and the system it requires **staff** who are willing to listen, and are able to assist farmers in analysing their situation and in making decisions on how to solve problems, and provide a service to farmers instead of following instructions from supervisors.

This requires a **set up** whereby extension workers operate in the field as **facilitators** who work directly with the farming community and who have the possibilities to request specific assistance from a **support team** when needed.

For professionals to act as facilitators and trainers they should show a willingness and ability to learn from and work with people and thus a major reversal in the attitudes of professionals.

Facilitator

The main role of the facilitator will be to organise the communities, discuss their problems, assist in analysing these problems and identify possible solutions and need for additional information. The facilitator should be well acquainted with the farmers, must be able to facilitate and stimulate discussions. He/she should preferably be based at community level, but at least be in regular contact with the community and easy approachable for all categories of farmers. The facilitator should be aware of what technical information/assistance is available elsewhere that can be requested, he/she is the person who will provide the link between farmers and support staff for specific technical assistance if so required.

This implies that field workers are expected to cope with a range of farm level problems, though most often they have been taught only a narrow package of technical advice and inputs. Moreover, they were taught to take a known technology to rural communities and transfer this knowledge and enlist their co-operation. Their limited, mainly theoretical, training in extension combined with their uncertainty regarding technical matters and their assumed authority in the field led to a rigid attitude.

To implement a participatory approach successfully, the field workers should have considerable communication and motivation skills, in addition to some technical understanding of agriculture and aquaculture. They need to be supported by a network of specialists. They also need training to help rural people to organise themselves; to formulate priorities, and to 'pull down' required assistance from a network of specialists and local experimental stations. This requires more knowledge and skills of an extension agent than simply transferring a technical package to farmers; more skills than many extension workers possess at present.

Support Staff

Support staff should ideally consists of technical staff, based for instance at district or provincial level who can support the facilitators with information upon request. This team should be made up of agricultural specialists, and also of marketing and financial advisors who form a link between farmers and credit suppliers. Even the inclusion of health, nutrition and other advisors should be considered. It is apparent that only information for crops with real potential in the area should be made available. This means that aquaculture extension will be limited to those areas with sufficient water resources and with suitable soil and topographic conditions. The support teams should have access to up-to-date information, be informed about the developments elsewhere in the country and region, and must have the means, materials and skills to provide the information requested. This means that they should be able to come up with innovative solutions that may divert from textbook solutions.

The support staff should give introductions on the specific topics and new developments, and explain to farmers what support can be provided. This could be seen as an awareness campaign in which case the support team operates more on their own initiative. Most of their work however will be to respond to requests from the farming communities.

Reacting to the requests of farmers opens good possibilities for the linkage between extension and research and for conducting on farm research. It will always be necessary to have a few small research stations to conduct experiments, but most of the more applied research should be conducted at farm level by the farmers themselves, supported and guided by researchers.

Traditionally, field staff were controlled and their performance evaluated by measuring the measurable (i.e. number of visits made, total pond area, fingerlings distributed). However, these are not very useful measures of either effort or impact, but were easily registered and analysed by supervisors. When technical staff operate upon request by farmers, the usefulness and appreciation of the service becomes much more apparent. These opens the possibility to evaluate the service and make changes where required. If services of certain specialists are never requested then the conclusion should be drawn that either the specialist him/herself is not functioning properly, or the topic is not required for that region. Appropriate action can then be taken.

Required Resources

In any organisation, staff is the most important resource. Staff needs to be well trained and equipped to perform the assigned duties. The successful use of a more participatory extension approach relies heavily on the motivation and ingenuity of the field workers. To bring about the desired change in attitude and extension methods by extension staff, a thorough training and restructuring of the extension organisation is needed. This staff will have to use the local social network of the farmers to further disseminate the extension messages, and will need extension material adapted for such an approach.

The education system thus needs transformation in the style of teaching and learning. Training courses should not be lectures; instead institutions will need to provide creative learning environments, conditions in which learning can take place through experience, and through personal exploration and experimentation. Training and capacity building in the use of community development and participatory methods should occur in the field because field tasks require staff whose experience and competence are practical rather than academic.

Staff will need the means to perform their duties efficiently. The facilitator requires the means to contact farmers and to be in easy and efficient contact with the support teams. The support teams have to be able to visit farmers and provide assistance and information to the farmers. They also need access to up-to-date information on local and regional developments, market and price developments, policy changes, regulations, etc.

The financial requirements for such an extension service will vary between countries. In countries with high a population density and good infrastructure a facilitator can operate with a bicycle for transport to contact farmers, and telephone and email facilities for the contacts with the support teams. The support teams will require transport, extension material, and means to produce specific extension materials; good access to email and telephone. The process of developing good extension material is takes a long time and requires expertise. Efforts should be made to develop standard sets of materials that have been properly tested for their effectiveness and that can easily be modified to the local situation. These standard sets can be developed for a whole region with comparable conditions.

In countries with scattered farms, poor infrastructure, unreliable telephone services and no electricity in rural areas, other equipment is required. A facilitator may have to travel to the support teams in order to contact them and may require a motorbike for visiting farmers.

The size of the support teams also depends on the local situation. In a stable political and economic environment with good infrastructure and reliable markets, farmers may focus on cash crops and may want to specialise. The support team will thus only need expertise in a few disciplines. While under unstable conditions, and unreliable market situation farmers may focus much more on diversification and risk avoidance. Under those circumstances extension has to take the local situation and the specifics of farming households into consideration, and extension becomes much more complicated.

The set up whereby the extension service operates much more upon request of farmers opens the possibilities that farmers will contribute to these services. This can be an option when the service has proven its effectiveness and usefulness to the farmers.

This re-organised extension structure requires a smaller but much better qualified and better-equipped staff than is currently the case. It is obvious that there is a general lack of commitment to change, or even a lack of acknowledgement for the need for change. Financial constraints may also restrict change, but more than money, these changes need people who are genuinely interested to learn the lessons from past failures. Hence, it needs professionals who are open for change who look beyond technologies only and who are focused on learning from farmers rather than teaching. This requirement is probably the most difficult to fulfil.

A great obstacle for change is the service itself. Most people are afraid of changes and may resist anything that influences their own position. The present hierarchy goes from national level to provincial and district level and then to extension workers and farmers. The extension workers are in most cases the lowest trained and lowest remunerated staff in the extension service. They are seen as the ones executing orders from above and farmers are simply seen as recipients. In the proposed set up the farmer and facilitator are the key elements of the system. They analyse the situation and will initiate the process of information flow. The proposed extension service is designed as a system that supports the farmers with information that is wanted and needed by the farmers. The facilitator has to be well trained and equipped and will have an important role in deciding what is expected of the whole service. This means a complete change of the present hierarchy, something that is difficult to accept by those who control the system at this moment.

REFERENCES

Axinn, G.H. *Guide on Alternative Extension Approaches*. FAO. Rome. 1988. 148 pp.

Bainville**,** S. 1998. *Les Interrelations entre Changement Techiques et Changement Institutionnels.* Paper presented at the 15th International Symposium. 29 Nov. – 4 Dec. 1998 Pretoria South Africa, Association for Farming Systems Research Extension. p 572-586.

Binali, W. 1996. *Aquaculture Extension in Zimbabwe*. In: Report of the Technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa. H.W. van der Mheen (1996) FAO ALCOM Report 21. p 32-34.

Brummet, R. and B. Haight. 1996. *Research Development Linkages*. In: Expert Consultation on Small-Scale Rural Aquaculture by M. Martinez-Espinoza, FAO, FIRI R548. p 145-170.

Bweupe, C. and A. Woynorovich, 1996. *Aquaculture Extension Systems and Methods used in the Northern Province of Zambia*. In Report of the technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa. H.W. van der Mheen (1996) FAO ALCOM Report 21. p 35-36.

Chambers, R., 1993. Challenging the Professions – Frontiers for Rural Development*. (Intermediate Technology Publications) London.*

Chimitz, P., 1955. Tilapia and its Culture. A preliminary bibliography*. FAO Fish Bull. 8 (1): p 1-33.*

Coche, A.G., Vincke, M. and B.A. Haight, 1994. Aquaculture Development and Research in Sub-Saharan Africa: Synthesis of national reviews and indicative action plan for research*. Committee for Inland Fisheries of Africa, Technical paper, No. 23. Rome, FAO 1994. 151 pp.*

Cochroan, W.W. 1958. *Farm Prices, Myths and Reality*. Minneapolis: Univ. of Minnesota Press.

FAO. 1975. *Aquaculture Planning in Africa*. Report of the First Regional Workshop on Aquaculture Planning in Africa, Accra, Ghana, 2-17 July 1975. FAO ADCP Rep 75/1, 114 p.

Galbreath, F. and A.D. Ziehi. 1992. *Practique de l'élévage de Tilapia Nilotica en Milieu Rural en Côte d'Ivoire.* In Aquaculture Systems research in Africa. proceedings of a Workshop in Bouake, Côte d'Ivoire14-17 Nov. 1988. G.M Bernacseck and H. Powles. IDRC. p 337-357.

ICLARM/GTZ, 1991. The context of Small-scale Integrated Agriculture-Aquaculture Systems in Africa: a case study of Malawi*. ICLARM Stud. Rev. 18: 302 pp.*

Jiggins, J.L.S. 1998. *The Feminization of Agriculture* (IN PRESS IN WORLD AFFAIRS)

Leeuwis, C., N. Röling and G. Bruin. 1998. *Can the Farmers Filed School Replace the T&V System of Extension in Sub-Saharan Africa?* Paper presented at the 15th International Symposium. 29 Nov. – 4 Dec. 1998 Pretoria South Africa, Association for Farming Systems Research Extension.

Murnyak, D. and G. Mafwenga. 1996. *Extension Methodology Practised in Fish Farming Projects in Tanzania.* In: Report of the technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa. H.W. van der Mheen (1996) FAO ALCOM Report 21. p 29-32.

Mwakubo, S.M. and H.K. Maritim. 1998. *Commercialization of Smallholder Agriculture: the Case of Nakuru District, Kenya.* Paper presented at the 15th International Symposium. 29 Nov. – 4 Dec. 1998 Pretoria South Africa, Association for Farming Systems Research Extension. pp. 822-829

Peterson J.S. and M. Kalende. 1999. The *Role of Cooperatives and Other Forms of Associations in Managing Aquaculture Resources: The Case of Bandundu, Democratic Republic of Congo.*

Pretty, J.N. and R. Chambers, 1994. Towards a Learning Paradigm: New Professionalism and Institutions for Agriculture*. In: Scoones, I. and J. Thompson. Beyond Farmer First – Rural people's knowledge, agricultural research and extension practice. (Intermediate Technology Publications) London, pp. 182-202.*

Röling, N., J. Jiggins and C. Leeuwis. 1998. *Treadmill Success and Failure: the Challenge for FSR/E.* Paper presented at the 15th International Symposium. 29 Nov. – 4 Dec. 1998 Pretoria South Africa, Association for Farming Systems Research Extension.

Röling, N. and E. Van de Fliert, 1994. *Transforming Extension for Sustainable Agriculture: the Case of Integrated Pest Management in Rice in Indonesia*. In: Agriculture and Human Values, Vol. 11, No. 2/3, pp. 96-108.

Satia, B., 1989. A Regional Survey of the Aquaculture Sector in Africa South of the Sahara*. Rome, UNDP/FAO, ADCP/REP/89/36.*

Scholz, U and S. Chimatiro. 1996. *The Promotion of Small Scale aquaculture in Southern Region of Malawi; A reflection of extension approaches and technology packages used by the Maliwi-German fisheries and aquaculture development project*. In: Report of the technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa. H.W. van der Mheen (1996) FAO ALCOM Report 21. p 28-29.

Scott, J.C., 1976. The Moral Economy of the Peasant. *(Yale University Press) New Haven and London.*

Smith, L.J. and S. Peterson (eds.), 1982. Aquaculture Development in Less Developed Countries: Social, Economic and Political Problems*. (Westview Press) Boulder, Colorado.*

Van der Mheen, H.W. 1996. *Report of the Technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa*. FAO ALCOM Report 21. 46 pp.

Van der Mheen, H.W. 1999. *Compendium of the results of the ALCOM aquaculture Programme for Smallholder Farmers in Southern Africa.* FAO ALCOM Report. 37 pp.

Van der Mheen-Sluijer, J., 1989. The Human Side of Fish Farming. Report of a study tour to Bangui, Central African Republic. *FAO, Chipata, Zambia. Unpublished Report, 24 pp.*

Veverica, K. 1996. *Aquaculture Extension in Rwanda*. In: Report of the technical Consultation on Extension Methods for Smallholder Fish Farming in Southern Africa. H.W. van der Mheen (1996) FAO ALCOM Report 21. p 44-46.

APPENDIX VII: FIELD NOTES FOR AFRICAN FRESHWATER AQUACULTURE[§§§§§§§]

ABBREVIATIONS

AA .... Amino Acid
AI... Active Ingredient
BHC BH Carp .... Big Head Carp (*Aristichthys nobilis*)
BOD.. Biochemical Oxygen Demand
BS .... Back Site
BW... Body Weight
CAE .... Carbon Assimilation Efficiency
CC or C Carp.. Common Carp (*Cyprinus carpio*)
C/N .... Carbon/Nitrogen
COD... Chemical Oxygen Demand
CP .... Crude Protein
DAP .... Diammonimum Phosphate
DM... Dry Matter
DO .... Dissolved Oxygen
ELEV .... Elevation
FCR.. Food Conversion Ratio
FS... Fore Sight
FW .... Freshwater
GC or G Carp .... Grass Carp (*Ctenopharyngodon idella*)
HI... Height of Instrument
MAP... Monoammonium Phosphate
ME .... Metabolizable Energy
MW.. Molecular Weight
OA .... *Oreochromis aureus*
OM.. *Oreochromis mossambicus*
ON .... *Oreochromis niloticus*
Prawn .... *Macrobrachium rosenbergii*
SC or S Carp .... Silver Carp (*Hypophthalmichthys molitrix*)
SGR .... Specific Growth Rate
SP... Super Phosphate
SS... Standing Stock (at harvest)
STA.. Station
T... Time
TA.. Total Alkalinity
TLW... Total Live Weight
TSP .... Triple Super Phosphate

[§§§§§§§] Prepared by Randall E. Brummett, International Center for Living Aquatic Resources Management, B.P. 2008 (Messa), Yaoundé, Cameroun, 1999.

A series of eight manuals have been produced between 1981 and 1998, presenting the background knowledge necessary for applying the technical data given below. These manuals, also available in French and in Spanish, have been recently made available by FAO on a CD-ROM.

Coche, A.G. and Van der Wal, H. 1981. Simple methods for aquaculture. Water for freshwater fish culture. FAO Training Series, (4):: 111p.

Coche, A.G. 1985. Simple methods for aquaculture. Soil and freshwater fish culture. FAO Training Series, (6): 174p.

Coche, A.G. 1988. Simple methods for aquaculture. Topography. Topographical tools for fish culture.FAO Training Series, (16/1): 330p.

Coche, A.G. 1989. Simple methods for aquaculture. Topography. Making topographical surveys for fish culture. FAO Training Series, (16/2): 262p.

Coche, A.G.and Muir, J.F. 1992. Pond construction for freshwater fish culture. Pond-farm structures and layouts. FAO Training Series, (20/2): 214 p.

Coche, A.G.,Muir, J.F.and Laughlin, T. 1995. Pond construction for freshwater fish culture. Building earthen ponds. FAO Training Series, (20/1): 355p.

Coche, A.G.,Muir, J.F.and Laughlin, T. 1996. Management for freshwater fish culture. Ponds and water practices. FAO Training Series, (21/1): 233p.

Coche, A.G. and Muir, J.F. 1998. Management for freshwater fish culture. Farms and fish stocks. FAO Training Series, (21/2): 341p.

1. FACILITY DESIGN AND CONSTRUCTION

A. Design Criteria

- Optimum slope of site = 0.5-1 % .
- Maximum slope of site = 2.5% for economical dam construction (<3 m high).
- Bottom slopes on ponds = 0.1-0.2 %.
- Minimum pond depth 80 cm (with 40 cm drop-off at water-line).
- Deeper ponds (> 2 m) might allow better fish growth.
- 0.5 m freeboard in dug ponds, 1.0 m in dams and 1.5 m in flood areas.

Spillways: 1 m drop to prevent fish coming up.
3 cm max depth to prevent fish going down.
Width in SE U.S.: (ft) = $\frac{\text{watershed area (acres)} + 15\text{ ft}}{2}$

Dike slopes: Ponds <1000 m^2..........2.0:1
Ponds >1000 m^2..........2.5:1
Sandier soils 3.0:1
Outside wall.................1.5:1

Sump: Appx. 1 m below pond bottom.
Walled with gaps to prevent silting.
Able to hold all fish in pond.
Not too big to seine.

Drains: Drain slope = 1%
Inlet best at drain end (into sump is best).
Pond should drain in 1-3 days.

Drain pipe: 4-10 ha.........12-24"
Smaller.........8-10"

- Monk is best with >6" drain pipes.
- 6167 m^3 drained in 2.5 days with 1.8 m head + 6" drain pipe.
- Drain pipe should drop 30 cm into drainage canal to allow complete draining.

Tanks: Rectangular tanks should be L:W:D = 30:3:1 in order to maximize flushing efficiency. If water is limiting, reduce L.

B. Water Quantity

To estimate the amount of water available due to storm runoff from watersheds:

1. Determine hydrologic soil group for the watershed area of concern.
2. Obtain runoff curve number from table.
3. Measure rainfall.
4. Extrapolate between runoff curve numbers to determine storm runoff depth.
5. Multiply runoff depth by area of watershed to estimate water volume.

Runoff Curve Numbers:

Hydrologic Soil Group:	A	B	C	D
Cultivated Watershed				
W/O Conservation Treatment	72	81	88	91
W/Conservation Treatment	62	71	78	81
Pasture or Range				
Poor Cover	68	79	86	89
Good Cover	39	61	74	80
Meadow	30	59	71	78
Woods, Shrubs or Forest				
Thin Stand, Poor Cover, No Mulch	45	66	77	83
Good Cover	25	55	70	77
Farmsteads	59	74	82	86
Roads	74	84	90	92

Storm Runoff Depth (cm):

Runoff Curve Number (from above)	60	65	70	75	80	85	90
Rainfall							
2.54 cm	0	0	0	0.08	0.20	0.43	0.81
3.05 cm	0	0	0.08	0.18	0.38	0.71	1.17
3.56 cm	0	0.05	0.15	0.33	0.61	0.99	1.55
4.06 cm	0.03	0.13	0.28	0.51	0.86	1.32	1.93
4.57 cm	0.08	0.23	0.43	0.74	1.12	1.65	2.36
5.08 cm	0.15	0.36	0.61	0.97	1.42	2.03	2.77
6.35 cm	0.43	0.76	1.17	1.65	2.26	3.00	3.89
7.62 cm	0.84	1.30	1.83	2.44	3.18	4.04	5.03
10.16 cm	1.93	2.62	3.38	4.24	5.18	6.25	7.42
12.70 cm	3.30	4.19	5.18	6.22	7.34	8.56	9.86
15.25 cm	4.88	5.97	7.29	8.33	9.60	10.94	12.32
17.78 cm	6.60	7.87	9.19	10.52	11.91	13.36	12.24
20.32 cm	8.46	9.91	11.35	12.80	14.27	15.80	17.30
22.86 cm	10.41	11.99	13.56	15.11	16.69	18.26	19.02
25.40 cm	12.45	14.15	15.82	17.48	19.10	20.73	22.30
27.94 cm	14.53	16.36	18.11	19.86	21.54	23.22	24.82
30.48 cm	15.90	18.59	20.45	22.25	24.00	25.70	27.33

Discharge from horizontal pipe flowing full: $Q = A \times D$

Q = discharge in gpm
A = internal area of pipe opening
D = distance from opening to a point 12” above water fall.

Area of Pipe Openings:
2”……..3.1 in^2
3”……..7.1 in^2
4”……..12.6 in^2
6”……..28.3 in^2
8”……..50.3 in^2

Weir Formulae:

Q = discharge of stream in cfs
H = head on weir in feet (measured upstream)
L = length of notch in rectangular weir

Rectangular Weir: $Q = 3.33\, H^{3/2} (L – 0.2\, H)$
90° V-notch Weir: $Q = 2.54\, H^{5/2}$

Embody’s Formula: (discharge of a stream measured by timing a partially submerged float over a known distance)

$$R = \frac{W\,D\,A\,L}{T}$$

R = m^3/sec stream
W = avg. width of stream (m)
D = avg. depth of stream (m)
L = length of tested section (m)
A = bottom roughness constant (0.9 = smooth, 0.8 = rough)
T = time for a float to traverse L (secs)

Evaporation:

1. Measured in a Class A Pan (25 cm deep x 122 cm diameter), loss from Pan X 0.75 approximates loss from a pond surface.
2. Evaporation per month = $-9.94+5.039T$; $r^2=0.94$ (T = average temp over the month)

C. Soils

- Soil samples should be taken at 50-100 m intervals in a grid pattern; test holes should be at least 2 m deep.
- Minimum of 20% clay.
- Acceptable seepage and evaporation = 1-2 cm/day (10 cm from a 15 cm diameter hole in wet soil in 24 hrs.).
- If your pond bottom is > 60% clay, do not let it dry or cracks will increase seepage.

Soil Classification: Percentage of Dry Weight

Soil Classification	Sand (0.05-2mm)	Silt (0.002-0.05mm)	Clay (<0.002mm)	Hydrologic Group
Sand	86-100	0-14	0-10	A
Loamy Sand	70-86	0-30	0-15	A-B
Sandy Loam	50-70	0-50	0-20	B
Loam	23-52	28-50	7-27	B
Silty Loam	20-50	74-88	0-27	B
Silt	0-20	88-100	0-12	B-C
Clay Loam *	20-45	15-52	27-40	B-C
Sandy Clay Loam *	45-80	0-28	20-35	C
Silty Clay Loam *	0-20	40-73	27-40	C
Sandy Clay *	45-65	0-20	35-55	C
Silty Clay	0-20	40-60	40-60	C-D
Clay	0-45	0-40	40-100	D

* Best for pond construction.

Average Permeability:

Sand .... 5.0 cm/hr
Sandy Loam .... 2.5 cm/hr
Loam .... 1.3 cm/hr
Clay Loam.......... 0.8 cm/hr
Silty Clay .... 0.25 cm/hr
Clay.................... 0.05 cm/hr

Plasticity Index: (PI) = Liquid Limit (LL) - Plastic Limit (PL)

For dikes w/o clay core: 20-70% of particles < 0.1 mm
10-40% of particles < 0.05 mm
PI = 8-20%
LL = 35% is best for compaction

For dikes w/clay core: LL < 60%
PL < 20%
PI > 30%

For clay cores: PI > 30%
LL < 60%
PL < 20%

- Compressibility is generally proportional to PI.
- For best compaction, PI should be as close to 16% as possible.
- In fine soils: low compressibility .... LL < 30
  med compressibility .... LL 30-50
  high compressibility .... LL > 50

pH: mix 20g dry, powdered mud + 20 ml distilled water, stir intermittently for 1 hour, measure pH.

6.5-8.5............................... Best
5.5-6.5, 8.5-9.5 .... Marginal
4.0-5.5, 9.5-11.0 .... Requires Special Management (Lime, etc.)
<4.0, >11.0........................ No Good

D. Soil Compaction

- Packing coefficient (amount excavated soil compresses when packed to form dikes): 20-50% depending upon soil and packing equipment (i.e. for 1 m^3 of dike you need 1.2-1.5 m^3 of fill.
- Core trench: 0.5 m below pond bottom into at least 1 m thick clay

- For compaction soil should be slightly crumbly, very crumbly is too dry. It is too wet if it can be rolled out pencil-thick.
- Do not try to compact soil layers of more than 4-10" (4-6" for heavy clay). Compact in repetitive passes until the sheep's foot roller "walks out".
- With a bulldozer add 10% to dam height for settling, with a rubber-tired scraper, add 5%.

E. Cement

Materials per cubic meter of concrete (includes 10% wastage):

	Cement	Sand		Gravel	
		m^3	kg	m^3	kg
2 cm gravel	318 kg	0.48	705	0.55	886
2.5 cm gravel	250 kg	0.44	636	0.59	955
4 cm gravel	239 kg	0.47	682	0.65	1045
4 cm gravel (alt.)	205 kg	0.47	682	0.62	1000

F. Water Heating

Cubic Meters	Kilowatts to Heat Static Water in 24 hours 3°C	6°C	8°C	11°C	14°C
18.93	3.0	6.1	9.2	12.2	15.3
15.14	2.4	4.9	7.3	9.8	12.2
11.36	1.8	3.7	5.5	7.3	9.2
9.46	1.5	3.0	4.6	6.1	7.6
7.57	1.2	2.4	3.7	4.9	6.1
5.68	0.9	1.8	2.8	3.7	4.6
3.79	0.6	1.2	1.8	2.4	3.1
2.84	0.5	0.9	1.4	1.8	2.3
1.89	0.3	0.6	0.9	1.2	1.5
0.95	0.2	0.3	0.5	0.6	0.8

G. Pumping

$$P = V\,Q\,H / E$$

P = pump power (kw)
V = spec grav water (9.81 kN/m^3)
Q = discharge (m^3/sec)
H = head (m)
E = pump efficiency (0.6 for centrifugal pumps)

H. Wind Shear Fences

- 40-50% permeability is best (low trees, shrubs and hedges are good).
- Two rows separated by twice the height works best.
- Can reduce heat loss by 3°C and evaporation by 20% within 30X height of fence downwind.
- Solid fences increase evaporation by increasing turbulence.

I. Pond Rehabilitation

Problem	Possible Solutions
Excessive Water	A. Diversion ditch. B. Raise dam (enlarge pond). C. Add pond uphill.
Turbidity	A. Settling pond uphill. B. Diversion ditch. C. Plant watershed.

Excessive Seepage	A. Disk bottom and slopes to 4-6" and compact w/sheep's foot roller. B. As above followed by bentonite mixed into top 4-6" at 1-3 lbs/ft^2. C. Clay blanket 12" thick on bottom. D. Sodium polyphosphates if suitable. E. Core dikes. F. Water-proof linings. G. Puddling: Saturate bottom and work with hoe (Reduces seepage +/- 6X) H. 250 kg total solids/ha/wk of chicken litter for 4 wks.
Fish Escaping	A. Reduce depth of spillway to 3 cm. B. Large mesh screen (clean often!).
Fish Entering	A. (from above) Screen incoming water. B. (from below) Vertical drop of 1 m on spillway.
Shallow Edges	A. Raise dam. B. Excavate. Earth can be stored in piers.
Insufficient Water	A. Divert water from adjacent watershed. B. Reduce area of pond. C. Reduce seepage. D. Dig a well. E. Wind-shear fence.
Waves Damaging Dikes	A. Rip-rap. B. Wind-shear fence. C. Break-water upwind in pond.

J. Recording Levelling Data

STA	BS	HI	FS	ELEV
BM	5.23	105.23		100.00
1			4.56	100.67
2			3.00	102.23
TP	6.20	108.43		102.23
3			4.50	103.93

- add the BS to ELEV of BM to get HI
- subtract FS to STA 1 from HI to get ELEV of STA 1
- subtract FS to STA 2 from HI to get ELEV of STA 2
- TP is a BS to STA 2; add BS to ELEV of STA 2 to get HI
- subtract FS to STA 3 from new HI to get ELEV of STA 3

2. WATER QUALITY

A. Oxygen

- < 3.0 mg/l can effect growth, FCR, disease resistance.
- ON growth is not improved by DO>10% of saturation.
- 0.1-0.5 kg/m^3 of Silver Carp in unfed cages can reduce net plankton, but increases nanoplankton.

Solubility of Oxygen in Pure Water at Sea Level:*

°C	mg/l	°C	mg/l	°C	mg/l
15	9.76	21	8.68	27	7.86
16	9.56	22	8.53	28	7.75
17	9.37	23	8.38	29	7.64
18	9.18	24	8.25	30	7.53
19	9.01	25	8.11	31	7.42
20	8.84	26	7.99	32	7.32

* Saturation concentration is decreased by approx. 0.55 mg/l for each 300 m increase in elevation.

Theoretical tilapia O_2 Consumption: $Y = w^{0.82}$

Y = mg O_2 per fish per hour
W = average weight per fish (g)

Measured Tilapia O_2 consumption: 10 g O_2/100 kg fish/hr at rest
$\geq$30 g O_2/100 kg fish/hr active/feeding

Aerators:

Oxygen Transfer Rate *

Diffusers	(fine bubbles)	1.2-2.4 kg/kwh
	(med. bubbles)	1.0-1.6 kg/kwh
	(big bubbles)	0.6-1.2 kg/kwh
Paddlewheels		1.2-2.4 kg/kwh
Agitators (surface)		1.2-2.4 kg/kwh
Gravity (pump up)		1.2-2.8 kg/kwh
Venturi		1.2-2.4 kg/kwh
U-Tube		4.5-45.6 kg/kwh (with or w/o O_2)

* Theoretical values for pure water, 20°C, 0 mg/l D.O. Measured OTR for a medium-bubble diffuser system at 220-352 g/kwh.

B. Ammonia

- NH_3/NH_4^+ are in equilibrium in water. TAN (total ammonia nitrogen) includes both.
- <0.1 mg/l is generally OK.
- 0.5-1.0 mg/l total ammonia not uncommon in ponds at end of summer.
- 0.2 mg/l NH_3 can be dangerous.
- more dangerous when pH and temperature are high.
- less dangerous when [Ca^{++}] is high.
- 96 hr LC_{50} = 0.3-0.6 for Striped Bass in FW at pH 7.0, [Ca^{++}] = 5 mg/l.
- Tilapia LC_{50} for NH_3 = 2 mg/l in FW.
- Tilapia in tanks produce an average of 22g NH_3/100kg fish/day (range = 9-46)

Percentage of total ammonia in NH_3 form at different temps and pH's:

pH	20	22	24	26	28	30
7.0	0.4	0.5	0.5	0.6	0.7	0.8
7.2	0.6	0.7	0.8	1.0	1.1	1.3
7.4	1.0	1.1	1.3	1.5	1.7	2.0
7.6	1.6	1.8	2.0	2.4	2.7	3.1
7.8	2.5	2.8	3.2	3.7	4.2	4.9
8.0	3.8	4.4	5.0	5.7	6.6	7.5
8.2	5.9	6.8	7.7	8.8	10.0	11.4
8.4	9.1	10.3	11.7	13.2	15.0	17.0
8.6	13.7	15.4	17.3	19.4	21.8	24.5
8.8	20.1	22.4	24.9	27.6	30.7	33.9
9.0	28.5	31.4	34.4	37.7	41.2	44.8
9.2	38.7	42.0	45.4	49.0	52.7	56.3
9.4	50.0	53.5	56.9	60.3	63.8	67.1
9.6	61.3	64.5	67.6	70.7	73.6	76.4
9.8	71.5	74.3	76.8	79.3	81.6	83.7
10.0	79.9	82.1	84.0	85.8	87.5	89.1

C. Nitrite

- 96 hr LC_{50} = 0.4 mg/l for channel catfish fingerlings, 4.2 mg/l for adults at 22°.
- 1.0 mg/l has killed catfish.
- Toxicity reduced by high pH, alkalinity, hardness, chloride.
- Toxicity increased at higher CO_2 and temperatures.
- 5-10 mg/l NaCl counteracts 1 mg/l NO_2^- = 3-6 mg/Cl^- (NaCl = 60% Cl^-)
- 96 hr LC_{50} for Striped Bass = 13 mg/l in FW
- <0.5 mg/l generally OK for tilapia.
- 35 mg/l at 1 PPT Salinity
- 100 mg/l at 8 PPT Salinity

D. Denitrification

- Denitrification and ammonia volitilization removed 55% of added N in ponds (17). NH_3 removal by biofilters = 0.02-0.1 g/ft^2 of media surface/day.
- Nitrification destroys 7 mg/l TA/mg/l NH_3 oxidized.

E. Carbon Dioxide

- Can fluctuate 0-10 mg/l over 24 hour cycle in ponds.
- Up to 60 mg/l is O.K. with good oxygen.
- 50 mg/l is high in surface waters, 80-90 mg/l in ground water.
- 50-100 mg/l can stress and kill fish.

F. Alkalinity

- >20 mg/l TA to provide carbon for photosynthesis and buffer pH; 50-200 mg/l is best.
- 175 mg/l can form a calcareous fur and affect gills (4).
- Very high TA has been associated with opaque corneas in Tilapia (4).

Forms of Alkalinity in Water:

pH <5.5...........mineral acidity (H^+ is present)
pH 4.5-5.0........all CO_2 except mineral acidity

pH 4.5-8.3........HCO_3^- increasing, CO_2 decreasing

pH 8.3-9.0........almost all HCO_3^-

pH >8.3...........CO_3^{-2} increasing, HCO_3^- decreasing

pH 11.5-12 +......measurable OH^-

G. Temperature

For *O. niloticus*, no spawning below 20°C.

- *O. niloticus* can stand 8°C for a few hours.

Maximum Swimming Performance: 24°C for *Tilapia sparmanii*
28°C for *T. zillii* & *S. macrochir*
28-32°C for *O. niloticus*
32°C for *O. mossambicus* & *S. galilaeus*

H. Turbidity

- 20,000 mg/l can affect behaviour.
- 175,000 mg/l can lead to appreciable mortalities.
- Effective concentration is determined in test containers. Choose lowest dosage that settles flock in 1 hour.

Treatments:*

$Ca(OH)_2$	>200 mg/l
Barnyard Manure	2000 kg/ha
Cottonseed or Soybean Meal	75 kg/ha
Single or Triple Super Phosphate	25 kg/ha
Gypsum ($CaSO_4$) *	100-200 mg/l
Alum ($Al(SO_4)_3$) ***	25-30 mg/l

* apply total dose all at once, may require several treatments
** gypsum has some residual effect
*** each mg/l Alum destroys 0.5 mg/l TA

I. Electrical Conductivity

- Proportional to mineral content.
- Increases in response to certain pollutants: road salt, sewage and manure containing large amounts of nitrates and phosphates, inorganic fertilizers, run-off from mining operations, brines from drilling, leaky landfills.
- Reduced in response to: snow melt, rainfall, non-ionic particulate matter.
- Changes approximately 2% for every degree deviation from 25°C:

$$C_{25} = C_m \div 1 + 0.02\,(t_m - 25)$$

20-150 µmho/cm common in FW:

Distilled Water	0.5-2.0 µmho/cm
Rain, Snow	2.0-50 µmho/cm
Most Drinking Water	50-1,500 µmho/cm
Saline Waters	1,500-5,000 µmho/cm
Seawater	2,000 µmho/cm
Brine	100,000 µmho/cm

J. Atomic Weights of Selected Elements

C	12	O	16	Cl	35.5
S	32	P	31	Si	28
Al	27	Mg	24	Na	23
K	39	Ca	40	Fe	56

K. Misc. Constituents

pH: 6.5-9.0 at dawn tollerable for most species.
Iron (7): More than 0.5 mg/l can clog pipes.
Silica (7): More than 100 mg/l can clog pipes.
Copper (7): 0.1 mg/l will prevent a phytoplankton bloom.
Total Dissolved Solids: 50-500 mg/l in FW is safe.
Off-Flavor: Mixing and/or aeration between 3:00-5:00 pm reduced NH_3, algae and off-flavor in catfish ponds.

3. NUTRITION AND FEEDING

A. Feeding

- Fry should increase their weight by 50% every three days at 30°C.
- Max feed rate to keep DO>1.0 mg/l at dawn = 100 kg dm/ha/day or 4.0 kg N/ha/day.
- Pelleting can double production.
- Hard pellets give better FCR than floating pellets.

Feeding Rates for Tilapia in Ponds:

Size (g)	18-21	22-25	26-32
0.01-1.0	10%	15%	25%
1.0-20	7.5%	10%	15%
20-100	3%	6%	7.5%
100-300	1%	2.5%	3%

Feeding Tilapia in Tanks at 30°C:

Average Weight(g)	% BW/Day	Comments
0.02-0.5 to 1 *	20 - 15	40% CP, Continuous w/Auto-feeders
0.50-1.0 to 5	15 - 10	32-36% CP, Continous w/Auto-feeders
5 to 20	10 - 7 3	2-36% CP, Continous w/Auto-feeders
20 to 50	7 - 4 3	2-36% CP, Continous w/Auto-feeders
50 to 100	4 - 3.5	28-32% CP, Divided into 3-6 feedings
100 to 250	3.5 - 1.5	28-32% CP, Divided into 3-6 feedings
250 to 450	1.5 - 1.0	28-32% CP, Divided into 3-6 feedings

Food Conversion Ratios:

Tilapia at 10,000/ha w/25% CP	1.60
Colossoma at 10,000/ha w/25% CP	1.80
Tilapia at 2,500/ha w/25% CP	1.28
Colossoma at 2,500/ha w/25% CP	1.29
Grass Carp w/Eichornia	45-50
Grass Carp w/Sudan Grass	26
Grass Carp with Barley	3

B. Nutrition

- Protein for tilapia diets can be almost exclusively from plant sources.
- N X 6.25 = Crude Protein.
- Natural pond food organisms contain approximately 55% of DM as CP.
- 50-70% of tilapia growth in fed ponds is due to natural food web.
- Cottonseed meal can replace some soybean meal (up to 20% of the diet) in catfish diets. Higher might be OK with lysine supplementation. $\leq$ 900 mg/l of gossypol seems to be OK.
- In a 24% CP tilapia diet, up to 67% of fishmeal can be replaced by hexane-extracted soybean meal.
- Catfish growth was not reduced on an all-vegetable diet with 60% of protein coming from soy-bean meal.
- Carp growth was not affected by a 55% replacement of fishmeal with soy-bean meal.
- Colossoma growth was not reduced in an all-vegetable diet containing 27% CP from soy-bean meal.
- In tilapia diets, 50% replacement of grain with spirulina reduces growth.
- < 20% Azolla is probably OK for tilapia.
- Mixed feeds generally provide a better balance of amino acids.
- Too much or too little protein can reduce protein absorption and retention. 40% CP giving 90% absorption is best for *Clarias*.

Basic Tilapia Diet:

Dry Matter	>90%
Crude Protein	25%
Lipid	<10%
CH_2O	<25%
Crude Fiber	< 1%
Ash	<17%
Total Energy:Protein	6-10 kcal/g
Vitamin and Mineral Premixes	

Essential Amino Acids:

AA	% of CP
ARG	3.54
HIS	1.25
ILU	3.11
LEU	2.79
LYS	4.64
MET+CYS	3.21 [44% CYS (35)]
PHE+TYR	5.00
THR	3.57
TRY	0.57
VAL	2.29

Metabolizable Energy:

Avg. Fat .... 9.45 kcal/g X 0.90 digestible = 8.5 kcal/g
Avg. CH_2O .... 4.15 kcal/g X 0.60 digestible = 2.5 kcal/g
Avg. Protein .... 5.65 kcal/g X 0.80 digestible = 4.5 kcal/g

Digestibility:

1. Crude protein digestibility can usually be estimated accurately in mixed feeds by averaging the digestibility of the components.

2. CH_2O digestibility will usually be under-estimated using the above method.

3. Extrusion does not seem to affect digestibility for tilapias.

Lipids: Warmwater fish seem to need n6 (less unsaturated) fatty acids (as do land animals) while coldwater fish seem to need n3 fatty acids.

Simple Formulations for CP and ME:

% Nutrient in Source I - Desired % Nutrient in Mix = Factor A
% Nutrient in Source II - Desired % Nutrient in Mix = Factor B

$$\frac{\text{Factor A}}{\text{Factor A + Factor B}} = \text{\% of Source I in Mix}$$

$$\frac{\text{Factor B}}{\text{Factor A + Factor B}} = \text{\% of Source II in Mix}$$

Note: Be sure to determine least costs (i.e., $/kg protein, $/kcal ME).

Proximate Composition of Common Feedstuffs:

Feedstuff	% DM	% CP	% Dig. (tilap)	% Lipid	% Dig. (tilap)	% CH_2O	% Dig. (tilap)	% Fiber	DE (kcal/kg)
Alfalfa Meal	2	17-22	66	3-4	51	37-43	12	18-22	667
Dried Blood	92	75	3	2		9		1	
Cereals (avg)	88	11	84	3	85-90	7	41	4	2507
Oil Seed (mech extd)	92	43		7		27	59	8	
(solv extd)	91	46	79	2	81	28	17	10	3340
Rice Bran (w/germ)	91	13	71	14		41		12	
Wheat Bran (w/o germ)	89	50	71	4		53		10	2484
Meat-Bone Meal	93	51	68-78	10	77	2		2	3470

Vitamin	Deficiency Signs:	Rec. Level (mg/kg diet)
Thiamin (B_1)	Poor growth; loss of appetite; loss of color; cloudy cornea; loss of equilibrium; weakness; terminal convulsions; some fin degeneration.	60
Riboflavin (B_2)	Loss of appetite; darkened skin; cloudy cataract/lens; disorientation; skin, heart, eye haemorrages; photophobia; mortalities.	60
Pyridoxine (B_6)	Poor growth; loss of appetite; loss of balance; exopthalmia; mortalities.	20
Pantothenic Acid	Poor growth; loss of appetite; clubbed gills; flared operculae; exopthalmia; haemorrages.	40
Inositol	Poor growth; loss of appetite; skin lesions; haemorrages; bloated stomach.	400
Biotin	Poor growth; loss of appetite; dark coloration; convulsions; muscle wasting; blue slimy mucus.	10
Folic Acid	Poor growth; loss of appetite; dark coloration; exopthalmia; pale gills.	10
Choline	Poor growth; haemorrage in kidney, intestine.	2000
Nicotinic Acid (Niacin)	Poor growth; loss of appetite; skin haemorrage; erratic swimming; photophobia; high mortalities.	150
Cyanocobalamin (B_{12})	Loss of appetite; anaemia.	0.05
Retinol (A)	Loss of appetite; loss of weight; loss of color; fin, skin haemorrages; exopthalmia.	2000
□-tocopherol (E)	Poor growth; muscular wasting; exopthalmia; curved backs; mortalities.	100
Menadione (K)	Anaemia.	40
Ascorbic Acid (C)	Loss of Appetite; curved backs; poor growth.	200

Mineral Deficiency Signs:		Rec. Level (mg/kg diet)
Calcium	Loss of appetite; reduced growth.	3.0
Phosphorus	Loss of appetite; reduced growth; soft bones; head deformities; fatty viscera.	6.0
Magnesium	Loss of appetite; reduced growth; high mortalities; convulsions; soft bones; bent backs; calcium deposits in muscle, kidney.	0.5
Iron	Anaemia.	0.15
Zinc	Loss of appetite; reduced growth; high mortalities; skin, fin erosion; cataracts.	0.3
Copper	Reduced growth.	0.003
Manganese	Reduced growth; short body.	0.013
Selenium	Poor growth; muscular wasting; exopthalmia; curved backs; mortalities.	0.0004
Iodine	Thyroid hyperplasia.	0.001

NB: Although levels have not been determined, a pre-mix should contain some cobalt, sodium, potassium, chromium and chloride.

4. FERTILIZATION

A. Primary Productivity

- In tropical and sub-tropical climates, system should fix a maximum of 10g C/m^2/day depending upon intensity of sunlight.
- In Israel, 2-5g C/m^2/day (avg = 4) from manure only gave 20-30 kg/ha/day fish yield.
- Hourly gross primary productivity = 4.1-11.5 (avg = 7.6) mg C fixed/mg chlorophyll *a*.

Chlorophyll *a*: 2.9-115.5 υg/l (avg = 33.65) for unfertilized ponds
62.7-212.3 υg/l (avg = 107.22) for fertilized ponds

Oreochromis aureus **Production Relative to Phytoplankton:**

kg/ha = $-1.43 + 24.48x - 0.15x^2$ (r = 0.94) [υg/l chlorophyll *a*]
kg/ha = $-166.64 + 354.60x - 18.06x^2$ (r = 0.89) [υg C/m^2/day]
kg/ha = $2362 - 2927x + 967x^2$ (r = -0.84) [SDV (m)]
υg/l Cholorophyll *a* = $19.14(SDV^{-1.976)}$ (r = -0.79)

C/N Ratios: C : N = 6.0 is best; can be adjusted with NPK fertilizer
C : N > 15; bacteria will remove N from solution
Wide (sawdust, etc.) 40% C : 0.5% N
Narrow (meat, etc.) 40% C : 5% N
Microbes are appx. 50% C : 10% N

Carbon Assimilation Efficiency (CAE): % C in food fixed in microbe tissue
CAE for Bacteria = 5-10% (extra becomes CO_2)

BOD/COD (54): BOD = COD (BOD is a good indicator of total O_2 demand)
BOD < COD (material will take longer to decompose completely)
BOD > COD (material broke down prior to end of BOD period)
BOD declines by appx 50% for each 5° C decline in temperature.

B. Inorganic Fertilizers

- Fertilizers will not work when temperature < 18-20° C.
- Need: 0.5 mg/l P (equivalent to 8 kg/ha P_2O_5) and 1.4 mg/l N.
- Apply chemicals in slurry or on platform. Do not let fertilizers contact the pond bottom.
- Apply at least every two weeks at a rate sufficient to meet N,P needs, or if SDV >30 cm.
- CRSP reccommends 30 kg/ha N and 8 kg/ha P
- Do not exceep 4 kg N to keep NH_3 in safe range.
- For sufish ponds in Alabama: 13-26 kg/ha of ammonium polyphosphate (10-34-0) liquid or 20 kg/ha diammonium phosphate or 20 kg/ha TSP every two weeks or if SDV>30cm.
- Boyd: 9 kg/ha N, 9 kg/ha P_2O_5, 2.2 kg/ha K_2O per application.
- N:P of 1:1.5 best in FW; higher in salt/brackish water.

Nutrient content of common inorganic fertilizers:

	$N-P_20_5-K_2O$
UREA	40-0-0
DAP ($(NH_4)_2HPO_4$)	18-46-0 *,**
MAP ($NH_4H_2PO_4$)	11-46-0 **
$Ca(NO_3)_2$	15-0-0
NH_4NO_3	34-0-0 ***
$(NH_4)_2SO_4$	1-0-0
$NaNO_3$	16-0-0 ****
Super PO_4	0-20-0
TSP	0-46-0
KCl	0-0-60

* most available N source
** can result in ammonia toxicity if pH is high
*** explosive
**** will burn

CRSP Recommendations for NPK/Bran input system:

Month	Size of Fish (g)	Feed/ha/day (kg)	% Body Weight
0	30	22.5	2.5
1	60	39.6	2.2
2	90	54.0	2.0
3	120	64.8	1.8
4	150	81.0	1.8
5	180	81.0	1.5
6	220	99.0	1.5
7	260	100	1.5
8	300	100	1.2

NB: 10 of total fish population are Clarias.
Fertilization rate: 20 kg N + 8 kg P per ha per week dissolved in a bucket and broadcast. Measure P prior to application of fertilizer. If orthophosphate (soluable P) >0.1 mg/l, don't add P.

C. Manures

- Maximum rate: 120 kg/ha/day of dry organic matter; usually = 2.5-4% fish biomass/day.
- Max rate should produce 3000 kg/ha of tilapia.
- Use as fine a particle as possible (powdered or slurried)
- Distribute evenly over pond
- Apply daily in mid-morning
- Use fresh -Do Not Compost-
- In Israel: 46% replacement of pellets w/cow manure did not reduce carp or tilapia growth.
- 100% replacement reduced growth by 47% (carp were much more affected than tilapia)
- Variability increased as manure replacement rate increased.
- Chicken litter is as good as feed for 1st 2-3 months of tilapia grow-out.
- For all initial applications of chicken manure, put in a thin layer over the entire pond bottom and flood with 10-20 cm of water. Let this sit 1 week and then fill the pond.

Wohlfarth's Reccommendations:

Standing Crop (kg/ha)	Dry Matter (kg/ha/day)
500	50
1000	80
1500	90
2000	120
2500	130
3000	140
3500	170
4000	190

Composition of Common Manures:

%	Pig	Chicken	Duck	Goose	Milk Cow	Beef	Sheep
Water	71	56	57	77	85	85	77
Org Matter	25	26	26	14	17		
Nitrogen	0.5	1.6	1.0	0.6	0.5	0.7	1.4
P_2O_5	0.4	1.5	1.4	0.5	0.2	0.5	0.5
K_2O	0.3	0.9	0.6	1.0	0.5	0.5	1.2
Calcium	0.09	2.4	1.8	0.9			
BOD/COD	3.3	4.3				5.7	7.2

D. LIME

- Beware of impurities!
- One month or so is usually required to see effects.
- Do not lime during a fertilization program as lime will precipitate all PO_4 in solution.
- Liming is best done prior to filling or during winter.
- Ag Lime is usually a mixture of dolomitic and calcitic limestones.
- Do not exceed 250 kg/ha with CaO or $Ca(OH)_2$.
- Liming must usually be repeated after 10 water changes or 2-4 years.

$$\text{Liming Rate} = \frac{\text{Lime Requirement}}{\text{NV X ER}}$$

Lime Requirement Estimation (kg/ha):

Mud pH*	Heavy Loams or Clays	Sandy Loams	Sand
<4.0	14300	7200	4500
4.0-4.5	10800	5400	4500
4.6-5.0	9000	4500	3600
5.1-5.5	5400	3600	1800
5.6-6.	3600	1800	900
6.1-6.5	1800	1800	0
>6.5	0	0	0

NB: In ponds with such high water flows that liming only lasts one year, use $Ca(OH)_2$: $Ca(OH)_2$ (mg/l) = required TA (mg/l) - TA initial (mg/l) X 0.74

Neutralizing Value (NV) is related to CaCO:

$$\text{NV} = \frac{\text{MW of Liming Material}}{\text{MW of } CaCO_3 = 100} \text{ X } 100$$

Quicklime, unslaked (CaO)...................................... 179%
Slaked, hydrated lime ($Ca(OH)_2$) 135%
Dolomitic ($CaMg(CO_3)_2$)....................................... 108.5%
Calcitic ($CaCO_3$).. 100%
Basic Slag.. 50-79% *

* Do not use silicate slags!

Efficiency Rating (ER) is calculated with the use of sieves:

% through No. 60 (0.25mm) X 100% = _____
% through No. 20 (0.85mm) X 60% = _____
% through No. 8 (2.36mm) X 20% = _____

Sum = ER

5. GROWTH AND PRODUCTION

A. Growth Parameters

- Up to 350 g, SR = 10,000 /ha should be considered a minimum for tilapia or colossoma fed 25% CP pellets. Up to this density, GR is not affected by SR.
- Q_{10} for Fish ~ 2.5
- CC for small fish > for large fish

Length/Weights of Tilapia:

Length (cm)	Weight (g)
10	20-25
12.5	30-45
15	50-60
17.5	80-110
20	115-145

Predator/Prey Ratios for Tilapia Production:

w/*Cichla ocellaris* 1:15 (21,59)
w/*Clarias lazera* .... 1:10 (21) [5-10% in Kenya (4)]
w/*Lates niloticus* .... 1:250 (45) (1:5 in Sudan)
w/*Cichlasoma managuens* .... 1:4 - 1:8 (19)
w/*Hemichromis fasciatus* .... 1:48 (5) [2% in Kenya (4)]

Single Crop Growth Predictors: $W_t = W_0 e^{gt}$ where $g = \ln W_t/W_0$

$$W_t = W_0 e^{kt} \quad \text{where } k = \frac{\text{\% BW Fed per Day}}{\text{FCR}}$$

Raceway Production of Tilapia:

1. mix sizes to maximize space utilization
2. grade out slowest-growing 10%
3. expect appx 2% mortality
4. carrying capacity: recirculation system = 50 kg/m^3 = 40 kg/l/sec H_2O flow
   flow-through system = 100 kg/m^3 = 120 kg/l/sec H_2O flow or 8-10 m^3 water/hr/ton of fish

Stocking rate and production in tanks at 30°C:

Stock Rate (per m^3)	Wt_i (g)	Wt_f (g)	Time (days)	AGR (g/day)
8000	0.02	0.5-1	30	-
3200	0.5-1	5	30	-
1600	5	20	30	0.5
1000	20	50	30	1.0
500	50	100	30	1.5
200	100	250	50	2.5
100	250	450	70	3.0 (~ 1% bw/day RGR at 450 g)

B. Reported Yields

- Tilapia fed 25% CP at 10,000/ha .... 3361 kg/ha
- Colossoma fed 25% CP at 10,000/ha .... 3682 kg/ha
- Tilapia unfed in cages in catfish ponds (100 fish/m^3) .... 34 kg/m^3
- Common Carp in cages with feed .... 110 kg/m^3

- *ON* fed 10 kg/dm chicken poop/ha/day + Urea and TSP (5 kg N & 1.2 kg P/ha/day):

10,000 fish/ha .... 6562 kg/ha/yr @ 335g
20,000 fish/ha .... 8863 kg/ha/yr @ 230g
30,000 fish/ha .... 12349 kg/ha/yr @ 214g
10,000 fish/ha + 10,000 after 2.5 mos .... 10047 kg/ha/yr @ 230g
20,000 fish/ha + 10,000 after 2.5 mos .... 8307 kg/ha/yr @ 230g

- *ON* fed 50 kg/ha/day DM Bagasse + 2.0 kg N and 0.2 kg P .... 4000 kg/ha

- 30,000 fish/ha, dissolved inorganic carbon = 20-30 g/m^2, 1 g dm chicken poop/m^2/day + Urea and TSP to give total N:total fertilizer ration of 4:1

75 day grow-out ....50 kg/ha/day
50 day grow-out ....32 kg/ha/day

Macrobrachium:

- Need 30% cp pellets (extruded is best)
- 8 per m^2 is too many
- Large variation in size by the time they reach >35 g; not too much at 17 g.

Closed system w/5-10% water exchange; dry feed of egg, milk pwdr w/binder gave 35% survival, 30% metamorphosed; hvstd 30 pl/l

- Open system w/ 50% exchange per day gave 60-80% survival; at 3.5 per m^2 grow-out; 72% survival

C. Specific Growth Rates $\left(\dfrac{\ln \text{final wt} - \ln \text{initial wt}}{T_2 - T_1}\right)$

SGR :		**Δ wt(g)**	**T(d)**	**SGR**
O aureus (9120/ha) w/1750 mullet,	Tilapia	13- 100	98	0.021
1400 SC, 4540 CC; total production	Mullet	156- 500	244	0.005
= 9267 kg/ha POND	Silver Carp	29-1106	245	0.015
	Common Carp	195-2268	245	0.010
TN X TA (male) (2000/ha)	Tilapia	148- 487	123	0.010
w/1720 SC, 3444 CC(s), 3000 CC(b)	Silver Carp	200-1311	143	0.013
Total Production = 5990 kg/ha POND	C. Carp (sm)	15- 230	122	0.022
	C. Carp (lg)	50- 942	143	0.021
ON X OA (male) (2850/ha)	Tilapia	48- 288	99	0.018
w/3120 CC(s), 3230 CC(b), 1600 SC,	C. Carp (sm)	10- 235	96	0.033
1180 mullet; Total Production	C. Carp (lg)	387-1018	99	0.010
= 4670 kg/ha POND	Silver Carp	416-1000	85	0.010
	Mullet	160- 430	85	0.012
O.N (178000/ha), feed rate 11 kg to 60 kg/ha POND		1- 27	63	0.052
O. aureus (5000/ha) supp to 500 kg,	Tilapia	25- 354	112	0.024
then 25% cp pellets. W/2500 CC,	Com Carp	31- 821	112	0.029
1120 SC; Total Prod. = 4900 kg/ha POND	Silver Carp	600-1443	112	0.008
O aureus (5000/ha) as just above	Tilapia	21- 295	114	0.023
W/3580 CC, 1500 SC, 30 GC	C. Carp	16- 694	114	0.033
Total Production = 4000 kg/ha POND	Silver Carp	3- 500	114	0.045
	Grass Carp	20- 138	114	0.017
Common Carp (2590/ha) as just	C. Carp	68- 829	193	0.013
above W/30 BHC, 710 SC, 1290 GC	Big Hd Carp	1800-2500	193	0.002
Total Production = 3500 kg/ha POND	Silver Carp	710-1700	193	0.005
	Grass Carp	16- 140	193	0.011
Silver Carp (4244/ha) fed by	S. Carp	39- 580	175	0.015
61 Pigs/ha. W/844 CC, 261 BHC,	Com. Carp	18- 360	175	0.017
67GC ; Total Production = 3000 kg/ha	Big Hd Carp	46-1520	175	0.020
POND	Grass Carp	313-1750	175	0.010
ON (10000/ha) fed 32% cp + 35,000	Tilapia	0.14-39	70	0.080
prawns (65% survival); SS = 394 kg/ha POND	Prawn	0.02- 6.5	70	0.083
ON + Prawns as above	Tilapia	30- 64	70	0.011
(79% prawn survival); SS = 713 kg/ha POND	Prawn	0.02- 4.5	70	0.077

O niloticus (5000 or 10000/h) w/36% CP		5- 14	104	0.032
Colossoma (10000/ha) w/25% CP		33- 426	129	0.020
O aureus, no feed, 600 fish/m^3 CAGE	mod phytopl	2.9-29	70	0.033
	dense phytopl	2.9- 73.8	70	0.046
All-male *ON*, 25% cp, 4-6% bw/day, 300/m^3, DO <5 mg/l CAGE		49- 271	122	0.014
OA 500/m^3,40% cp pellets CAGE	floating feed	25- 127	87	0.019
	sinking feed	25- 172	70	0.022
Taiwan Red Tilapia, 125/m^3,	fed	8.7-22.7	56	0.017
in prawn ponds, 90% male CAGE	not-fed	9.1- 14	56	0.008
Taiwan Red Tilapia, 125/m^3 in	fed	9- 32.4	56	0.023
shrimp ponds, 90% male CAGE	not-fed	8- 22.4	56	0.018
Florida Reds, 400/m^3, 36% cp	no aeration	46- 361	145	0.014
ad lib., all male CAGE	24 hr aeration	52- 354	145	0.013
Florida Reds, 600/m^3	no aeration	54-321	145	0.012
36% cp ad lib., all male CAGE	24 hr aeration	47-341	145	0.014
OA salt water, 400/m^3, fed 36% cp, 6% bw/day CAGE		24-68	90	0.012
Florida Reds, 300/m^3, salt water CAGE	fed ad lib.	9-150	84	0.033
	fed 50% of sat	13-94	84	0.024
O niloticus, fed 32% cp,	250 fish/cage	14-221	169	0.016
13,000 fish/ha, mixed sex CAGE	500 fish/cage	14-186	169	0.015
	750 fish/cage	14-170	169	0.014
	1000 fish/cage	14-171	169	0.015
O niloticus, 35 fish/m^3,	no feed	13-72	153	0.011
5% bw/daypellets (20% cp) CAGE	feed	3.5-109	153	0.014
	weeds	17- 71	153	0.009
O niloticus, 20% cp,	400 fish/m^3	61.5-244	150	0.009
3% bw six times/day CAGE	600 fish/m^3	89.5-330	150	0.009
	1000 fish/m^3	163-382	150	0.006
	1200 fish/m^3	155-346	150	0.005
45 fish/m^3, 28 % cp diet	*O. mossossambicus*			0.014
fed 5% twice/day CAGE	*C. carpio*			0.014
	P. javanicus			0.013
	Trichogaster spp.			0.028
Channel catfish, 600 fish/m^3		7.3- 108	126	0.021
32% cp, 3% bw/day CAGE		16.2- 133	126	0.017
		51- 269.5	126	0.013
		93-380	126	0.011
O niloticus and *O aureus* (30 kg/m^3) recirculating RACEWAY		29- 167	137	0.013
O aureus at 78 fish/m3 recirculating/hydroponic RACEWAY		20- 400	183	0.016

6. INTEGRATION

A.Plants

- FCR for leaves and veg waste = 30-40:1
- w/rice in China...10% more rice + 450 kg/ha fish

B. Animals

Pigs: 100 pigs/ha w/20,000 tilapia
5.1% TLW manure production
5% bw pig feed
pigs grow from 50 up to 100 kg in 6 mos
pigs need 1.6 m^2/animal floor space

Ducks: In Asia (for egg production):
8000 ducks/ha w/20,000 tilapia
5.7% TLW manure production
feed ducks 140 g duck feed/day/duck
house ducks at 10 per m^2
60% of ducks in eggs per day
4-6% conversion of waste into fish
fish grow about 1.22 g/day

In Europe (for meat production):
300 ducks/ha w/500 carp
9.6% TLW manure production
ducks grow to 2.5 kg in 50 days
house ducks at 10/m^2
waste conversion = 4-6%
fish grow about 5.8 g/day

Geese (fattening):
80 geese/ha w/1800 tilapia, 2500 CC, 1500 GC
geese grow from 2 kg up to 4.5 kg in 2 mos
feed geese 40 kg/100 birds/day of the following:
Sorghum:Wheat:Rice = 10:15:17 + 12 kg grass/100 birds/day
house geese at 7-10 birds/m^2
FCR = 0.99:1 plus waste feed

Chickens (broilers):
5000 chickens/ha w/16,000 tilapia
2 kg dm per 1000 birds per day manure production
feed ad libidum
chickens grow to 1.2 kg in 50 days
house at 8/m^2
FCR = 3.1

Cattle: 250 cattle per hectare
0.89% TLW daily manure production
FCR = 3.1

Sheep and Goats:
400-450/ha
1.1% TLW daily manure production
10 kg grass per animal per day plus:
goat supplement: 5 kg rice bran + 5 kg cottonseed meal
sheep supplement: 4 kg soy bean cake
FCR = 3.1

C. Fish Silage

Basic Steps in Production:

1. freezing of primary ingredients at -5 seems to enhance feed efficiency.
2. mincing.
3. liquifaction via in situ enzymes in an acid environment: pH always between 4.0-4.5

2% H_2SO_4 + 0.75% Proprionic acid (pH 4.0) OR 0.75% Formic + 0.75% Proprionic OR 2.5% H_2SO_4 + 1.2% Proprionic OR 1.5% H_2SO_4 + 1.5% Formic OR 3% Formic acid alone

4. de-oiling or addition of anti-oxidants (ethoxyquin).
5. water removal.
6. incorporation into feed (50:50 w/commercial feed + vits + binder)
7. extrude through perforated plate and
8. use as moist pellets

Note: 5 and 6 are most easily done by co-drying (i.e., mixing dry ingredients with silage and then sun or oven drying).

7. PARASITES AND DISEASES

A. Prophylaxis

NaCl*:	10-20 mins in 10 g/l solution 30-60 secs in 30 g/l solution 1-3 g/l in transport water
Delta Blue:	1 kg/m^3 for 1 hour
Acriflavin:	10 mg/l for 1 hour 2 mg/l indefinite
Terramycin*:	in feed (5.5 g/100 kg fish) for 12 days

B. Bacterial Infections

Terramycin:*	in feed (5.5g/100 kg fish) for 12-14 days 20 mg/l in solution single 44 mg/kg intramusc./peritoneal injection
Nitrofurazone:	in feed 18-22 g/100 kg fish for 12-14 days 20 mg/l indefinite in water (repeat every 4 days)
Furacin:	20-100 mg/l (15 mg/l A.I.) for 1-2 hours
Furanace:	0.05-0.1 mg/l indefinite 0.6 mg/l for 1 hour 1 mg/l for 5-10 mins for 2-3 days
Furazolidone:	in feed 30-100 mg/kg of fish for 3 days
Acriflavin:	2 mg/l in solution (indefinite) 10 mg/l for 1 hour bath
$KmnO_4$:*	2-4 mg/l effective [] (depends on organic matter in the water). Can lead to DO depletion.

Erythromycin: single 44 mg/kg intramusc./peritoneal injection

Sulfamerazine:* in feed (18-22 g/100 kg fish/day) 10-14 days

Roccal/Hyamin 35:	2 mg/l A.I. for 1 hour for 3 days
Kanamycin:	in feed 50 mg/kg fish for 7 days

- Approved for use on foodfish by USFDA.

Preparation of Medicated Feeds: Dissolve chemical in 1 pt of oil/25 kg of feed.

C. Parasitic Infections

$CuSO_4$:*	< 20 mg/l T.A.; do not use 20-50 mg/l T.A.; 0.25-0.5 mg/l 50-100 mg/l T.A.; 0.5-0.75 mg/l 100-150 mg/l T.A.; 0.75-1 mg/l 150-200 mg/l T.A.; 1-2 mg/l Can cause DO depletions. 20-60 sec dip 4 ml $CuSO_4$ solution + 50 g NaCl/l $CuSO_4$ solution = 120 g $CuSO_4$ + 1.5 ml HOAc + 1 l H_2O
$KmnO_4$:*	5 mg/l for 20 mins (clear water) 2 mg/l indefinite (clear water) Can cause DO depletions.

Formalin:* 15-25 mg/l indefinite
(37% Formaldehyde) 250 mg/l dip when temp. <16°
170 mg/l dip when temp. >16°
Can cause DO depletions.

Dylox: 0.25-0.5 mg/l (80% A.I.) indefinite
(temp 10-27) once each week for 4 weeks
(do not use if pH>8.5)
(aka: Dipterex, Masoten, Proxol, chlorofos, foschlor, trichlorofon, Malathion)

Malachite Green (Zn free): 0.1 mg/l indefinite (0.14 mg/l can kill)

NaCl*: 10-30 g/l for 5-10 mins; 1-5 ppt for ICH

Acetic Acid*: 2 g/l for 30 secs

Di-N-Butyl Tin Oxide: 1% in feed

Yomesan: in feed 50 mg/kg fish for 3 days (0.05% the weight of the food)

D. Fungal Infections
Malachite Green 60 mg/l for 15 minutes (may kill fish)

$CuSO_4$ * (see parasitic infections)

Approved for use on foodfish by USFDA.

E. Prophylaxis and Therapy of Egg Infections
Malachite Green .... 1-5 mg/l for 15 mins/day
Formalin * .... 250 mg/l for 1 hour for catfish (do not use w/in 24 hrs of hatching)
Merthiolate .... 200 mg/l for 10 mins
Acriflavin .... 400 mg/l for 30 mins
Betadine .... 200 mg/l for 30 mins

F. Shipment of Specimens for Diagnosis

Preservation	Parasites	Bacteria	Virus	Histopathology
Live	+++	+++	+++	+++
Iced	+	++	+++	+/-
Frozen	-	++/+	++/+	-
Formalin*	+/-	-	-	+++

10% formalin at a 10:1 solution to fish ratio.

8. WEEDS

A. Prevention

- minimum pond depth = 60 cm
- maintain maximum SDV of 30cm

B. Control

- Grass Carp at 50-150 per hectare. (filamentous algae, submerged weeds, duckweed)
- Periodic draw-down of pond to dry weeds on pond edge (do not use on Hydrilla)

Chemical Control:

Weed	Chemical	Rate	Comments
Planktonic Algae	$CuSO_4$-$5H_2O$	0.25-1 mg/l	Depends upon T.A.
	Simazine	0.5-1 mg/l	Apply as slurry.
Filamentous Algae	$CuSO_4$-$5H_2O$	0.5-2 mg/l	Depends upon T.A.
	Simazine	1.25 mg/l	Apply as slurry.
Chara/Nitella	$CuSO_4$-$5H_2O$	1-3 mg/l	Depends upon T.A.
	Simazine	1.25 mg/l	Apply as slurry.
Pondweed, Naiad Ceratophyllum, Elodea, Utricularia, Cabomba	Diquat	0.25-2 mg/l	Inject below surface. Do not use in muddy water.
Pondweed, Naiad Ceratophyllum	Endothol	2-5 mg/l	Inject below surface or broadcast.
Pondweed, Naiad Cabomba	Simazine	1-3 mg/l	Apply as slurry.
Myriophyllum	2,4-D (granules)	25 kg/ha	Broadcast when weeds are growing.
Duckweed	Diquat	0.25-1 mg/l	As above.
Duckweed, Eichornia	2,4-D (liquid)	5 kg/ha	Spray on foliage.
Waterlily, Lotus	Dichlobenil	7.5-10 kg/ha	Broadcast pellets.
Spatterdock	2,4-D (granules)	35-50 kg/ha	Broadcast.
Cattails, Rushes	Dalapon	6-25 kg/ha	Spray on foliage.
Grasses	Roundup/ Rodeo	3-5 kg/ha	Apply to foliage, not to water.

Days between Treatment and Water Use:

Chemical	Drinking	Swimming	Consume Fish	Animals	Irrigation
Copper	0	0	0	0	0
Dalapon	*	*	*	*	*
Dichlobenil	*	*	90	*	*
2,4-D	*	1	3	*	*
Diquat	14	10	10	10	10
Endothol	7-25	1	3	7-25	14
Simazine	365	0	0	365	365

* No specific regulations. Use caution.

9. HATCHERY MANAGEMENT

- Larvae develop faster in warm water, but larvae grown in cooler water are larger at end of yolk absorption as they are less active during absorption and therefore put more energy into growth.
- Yolk-conversion efficiency is lower at higher temperatures yielding smaller fry.
- Filling ponds at night can minimize *Xenopus* infestation.
- To remove bacteria from in-coming water use Chloramine-T hydrate at 1 g/l at pH 7.5 (more toxic at lower pH, less effective at higher pH).
- Female tilapia can produce a batch of eggs every 4-6 weeks.
- Egg production increases approximately in relation to the square of body length in *Oreochromis* and *Sarotherodon* and the cube of the body length in *Tilapia*.
- In *O. niloticus* at 8 weeks of age (2-4 g), no difference between sexes in average weight.

Grading Tilapia:

Rakocy		Armitage et al.	
Weight (g)	Gap Width (cm)	Weight (g)	Gap Width (cm)
5	1.00	10	1.0
10	1.30	20	1.2
25	1.75	30	1.6
250	3.50	50	2.0

Hapa Spawning of Tilapia:

1. Stock brooders at 0.5-1 fish/ft^2 (2 females/male)
2. Feed at 2% BW/day
3. Hapa L:W:D = 10:4:4 with 1/16" delta style mesh
4. Collect all fry in 10-20 days (w/in a few days of first sighting)
5. Collect eggs and sac-fry for incubation
6. Production should be 3 fry + 3 eggs/sac-fry per ft^2 per day
7. Expect 20% predation mortality on fry and small fingerlings in ponds

Fry Pond Preparation: Stocking rate = 1.5 million per ha
Consider green manure, lime, supplemental feeds after 2-3 days.

Fertilization:

1. Cattle Manure @ 10-15 Tons/ha 2 wks prior to stocking; 5 Tons/ha/wk after stocking
2. Chicken Manure @ 1/3 of above rates
3. Compost @ 5 tons/ha 2 wks prior to stocking; 5 tons/ha/wk after stocking

Predator Control: Dylox @ 0.25 mg/l A.I. just prior to stocking or diesel oil with soap

Egg Diets for Larvae:

1. Break egg into heat resistant container.
2. Beat or blend
3. While stirring constantly, rapidly pour in boiling water (150 ml/egg).
4. OR. Pour blended egg directly into boiling water; amount of stirring determines particle size.
5. OR. Hard boiled egg yolks can be used directly.

Carp Pituitaries:

1. Store fresh in absolute alcohol; replace alcohol after 24 hrs; OK at room temp for 1 year, in frigo for 2-3 years.
2. Actone dried: use 10X gland volume of acetone. Replace acetone after 12 hrs. Replace again after 6-8 hrs. Dry and store for up to 3 years.

Spawning Induction:

1. Priming Dose: 2-4 mg/kg of female
2. Resolving Dose: 8-12 mg/kg of female after 6-12 hrs
3. For Males: 2-4 mg/kg of male at time of resolving females

NB: Injections should not exceed 1 ml including saline (pH 7.4).

Hormone Feed Formulation:

1. Ingredients: 5 kg feed (35-40% cp), 0.25 g -methyltestosterone (50 mg/kg feed), 4 l alcohol (dentured O.K.)
2. Mix feed to pass a 1 mm sieve.
3. Stir hormone into alcohol until completely dissolved.
4. Mix alcohol/hormone into feed.
5. Place feed on plastic sheet to dry.
6. Keep away from direct light or heat.
7. Stir frequently while drying.
8. Store in sealed container in freezer.

Hormone Sex-Reversal of Tilapias:

1. Fry size = 9-11 mm (2 wks old at 25)
2. Stocking density = 2500 fry/m^3 maximum
3. H_2O exchange = 10 l/min/m^3
4. Feed Rate = 20% bw daily divided into 8 feedings
5. Temperature = 25° C
6. Duration of treatment = 28 days

10. TRANSPORT

Species	**g fish/l H_2O**	**Hours**	**Temp (°C)**
Tilapia	100-200	24	8-28
Silver Carp	90		5
Silver Carp	25		25
C and BH Carp	280		5
C and BH Carp	50		30

NB: Use 1-3 g/l NaCl or 1 ml/l Benzocaine (stock sol'n = 100 g/l EtOH) to reduced stress.

Starve fish before transport:

Weight	Starvation Time
0.1 g	24 hrs
3.0 g	48 hrs
>3.0 g	72 hrs

Plastic Bags w/ Oxygen: g Fish/L H_2O = 38 X w
w = avg wt of fish (g)
put in 3 times as much O_2 as fish.

Tanks w/ Oxygen: kg of fish/ 2 l H_2O (< 3 hrs)
kg of fish/ 3 l H_2O (> 3 hrs)

Tanks w/o Oxygen: For 250 g Common Carp at 15:

	Transport Time (hrs)					
	2	4	6	8	10	12
l H_2O/kg of fish	4	5	6	7	8	9

Estimating Fish Weight via Water Displacement:

$$[(ft^3\ H_2O + Fish) - (ft^3\ H_2O)] \times 62.43\ lbs/ft^3\ H_2O \times 1.02\ lbs\ Fish/lb\ H_2O$$

11. CONVERSION FACTORS AND FORMULAE

A. Conversion Factors

Length:	1 inch = 2.54 cm
	1 foot = 30.48 cm
	1 yard = 91.44 cm
	1 statute mile = 5280 ft = 1.61 km
Weight:	1 avoir. ounce = 28.35 g
	1 avoir. pound = 16 oz = 454 g
	1 long ton = 2000 lb = 1.02 metric tons
	1 short ton = 2240 lb = 0.91 metric tons
Volume:	1 U.S. quart = 32 oz = 946.3 ml
	1 Imp. quart = 40 oz = 1.136 l
	1 U.S. gallon = 4 quarts = 231 in^3 = 0.1337 ft^3 = 3.785 l
	1 Imp. gallon = 4.546 l
	1 U.S. fluid ounce = 1.804 in^3 = 6.035 tsp = 29.57 ml
	1 cup = 8 oz = 14.43 in^3
	1 pint = 2 cups
	1 acre-foot = 43560 ft^3 = 325872.4 gal = 1230 m^3
Area:	1 acre = 43560 ft^2 = 4840 yd^2 = 4047 m^2
	1 square foot = 929.1 cm^2
	1 square inch = 6.452 cm^2
	1 square mile = 640 acres = 1 section
Temperature:	C = 5/9 (F - 32)
	F = 9/5 (C + 32)
Miscellaneous:	1 pound per acre = 1.12 kg/ha
	1 pound per square inch = 70.31 g/cm^2
	1 gal/min = 0.00223 ft^3/sec = 0.0631 l/sec = 5.42 m^3/day
	1 hp = 0.7457 kw

B. Geometric Formulae

Area:	parallelogram	$A = bh$	**Volume:**	cylinder	$V = bh$
	triangle	$A = 1/2bh$		circular cylinder	$V = \pi r^2 h$
	trapezoid	$A = 1/2h (b_1 + b_2)$		pyramid	$V = 1/3bh$
	circle	πr^2		cone	$V = 1/3\ \pi r^2 h$
	cube	$6e^2$		sphere	$V = 4/3\ \pi r^3$

Perimeter: circle $C = \pi d = 2\pi r$

BIBLIOGRAPHY

Facility Design and Construction

Boyd, C.E. 1985. Hydrology and pond construction. In: C.S. Tucker (ed). Channel Catfish Culture. Elsevier. Amsterdam.

Coche, A.G. 1985. Soil and freshwater fish culture. FAO Training Series: 6. Food and Agriculture Organization of the United Nations, Rome.

Coche, A.G. and H. Van der Wal. 1981. Water for freshwater aquaculture. Simple Methods for Aquaculture: 4. Food and Agriculture Organization of the United Nations, Rome.

Klemetson, S.L. and G.L. Rogers. 1983. Reduction of aquaculture pond heat losses. In: G.L. Rogers, R. Day and A. Lim (eds). Proceedings of the First International Conference on Warmwater Aquaculture - Crustacea. Brigham Young University Hawaii Campus. Laie, Hawaii, USA.

Lawrence, J.M. 1949. Construction of Farm Fish Ponds. Agriculture Experiment Station, Auburn University, Alabama, USA.

USDA (United States Department of Agriculture). 1982. Ponds: planning, Design and Construction. Soil Conservation Service Agriculture Handbook: 590. United States Department of Agriculture.

Water Quality

Boyd, C.E. 1979. Water Quality in Warmwater Fish Ponds. Agriculture Experiment Station, Auburn University. Auburn, Alabama, USA.

Boyd, C.E. 1990. Water Quality in Ponds for Aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama, USA.

Daniels, H.V. 1989. Water quality studies in brackishwater ponds. Ph.D. Dissertation. Auburn University. Auburn, Alabama, USA.

Delincé, G. 1992. The ecology of the fish pond ecosystem with special reference to Africa. Kluwer Academic, Dordrecht, The Netherlands.

Paessun, M.A. and R. Allison. 1984. Maximizing tilapia production in recirculating systems by sequential rearing. Aquaculture 42:185-189.

Philippart, J-Cl. and J-Cl. Ruwet. 1988. Ecology and distribution of tilapias. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds).The Biology and Culture of Tilapias. ICLARM Conference Proceedings: 7. International Center for Living Aquatic Resources Management. Manila, Philippines.

Rakocy, J. E. 1990. A recirculating system for tilapia culture and vegetable hydroponics. In: R. Oneal Smitherman and D. Tave (eds). Proceedings of the Auburn Symposium on Fisheries and Aquaculture. Auburn University. Auburn, Alabama, U.S.A.

Russo, R.C. and R.V. Thurston. 1991. Toxicity of ammonia, nitrite and nitrate to fishes. In: D.R. Brune and J.R. Tomasso (eds). Aquaculture and Water Quality. Advances in World Aquaculture: 3. World Aquaculture Society, Louisiana State University, Baton Rouge, Louisiana, USA.

Nutrition and Feeding

Akiyama, D.M. 1991. The use of soybean meal based feeds for high density cage culture of common carp in Indonesia and the People's Republic of China. World Aqauculture Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Carneiro, A.R.X. and R. Roubach. 1991. Experiments in the nutrition of *Colossoma macropomum* (Characidae). I. Feeding efficiency of vegetable and animal proteins. World Aqauculture Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Hepher, B. 1988. Nutrition of Pond Fishes. Cambridge University Press. Cambridge, England.

Jauncey, K. and B. Ross. 1982. A Guide to Tilapia Feeds and Feeding. Institute of Aquaculture. Stirling, Scotland.

Liou, C-H and E.H. Robinson. 1991. Lysine and sulfur amino acid requirement of juvenile blue tilapia, *Oreochromis aureus*. World Aqaculture Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Lovell, T. 1988. Nutrition and Feeding of Fish. AVI. New York, USA.

Naegel, L.C.A. 1991. *Azolla microphylla* as a feed ingredient for tilapias. World Aqauculture Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

NRC (National Research Council). 1977. Nutrient Requirements of Warmwater Fishes. National Academy of Sciences, Washington DC, USA.

Fertilization

Boyd, C.E. 1979. Water Quality in Warmwater Fish Ponds. Agriculture Experiment Station, Auburn University. Auburn, Alabama, USA.

Boyd, C.E. 1982. Liming fish ponds. J. Soil and Water Conservation 37(2):86-88.

Boyd, C.E. 1990. Water Quality in Ponds for Aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama, USA.

Knud-Hanson, C.F. 1998. Pond fertilization: ecological approach and practical applications. Pond Dynamics/Aquaculture Collaborative Research Support Program, Oregon State University, Corvallis, Oregon, USA.

Schroeder, G.L. 1980. Fish farming in manure-loaded ponds. In: R.S.V. Pullin and Z.H. Shehadeh (eds). Integrated Agriculture-Aquaculture Farming Systems. ICLARM Conference Proceedings: 4. International Center for Living Aquatic Resources Management. Manila, Philippines.

Growth and Production

Balarin, J.D. and J.P. Hatton. 1979. Tilapia: A Guide to Their Biology and Culture in Africa. University of Stirling. Stirling, Scotland.

Bardach, J.E., J.H. Ryther and W.O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley-Interscience. New York, USA.

Carro-Anzalotta, A.E. and A.S. McGinty. 1986. Effects of stocking density on growth of *Tilapia nilotica* cultured in cages in ponds. J.World Aquaculture Society 17:52-57.

Chiayvareeesajja, S. B. Sirikul, P. Sirimontraporn, S. Rakkeaw, R. Tansakul and A. Sornprasit. 1988. Comparison between natural feeding alone and supplemental feeding with pellets containing locally available ingredients for cage culture of *Oreochromis niloticus* in Thale Noi, Thailand. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedintgs: 15. International Center for Living Aquatic Resources Management, Manila Philippines.

Clark, J.H., W. O. Watanabe, D.H. Ernst, R.I. Wicklund and B.L. Olla. 1990. Effect of feeding rate on growth and feed conversion of Florida red tilapia reared in floating marine cages. J. World Aquaculture Society 21:16-24.

Dunseth, D.R. and D.R. Bayne. 1978. Recruitment control and producction *Tilapia aurea* (Steindachner) with the predator, *Cichlasoma managuense*(Günther). Aquaculture 14:383-390.

Guerrero, R.D., III. 1982. Control of tilapia reproduction. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds) The Biology and Culture of Tilapias. ICLARM Conference Proceedings: 7. International Center for Living Aquatic Resources Management. Manila, Philippines.

Hargreaves, J. A., J.E. Rakocy and D.S. Bailey. 1991. Effects of diffused aeration and stocking density on growth, feed conversion and production of Florida red tilapia in cages. J. World Aquaculture Society 22:24-29.

Hepher, B. and Y. Pruginin. 1982. Tilapia culture in ponds under controlled conditions. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds). The Biology and Culture of Tilapias. ICLARM Conference Proceedings: 7. International Center for Living Aquatic Resources Management. Manila, Philippines.

Knud-Hanson, C.F. and C.K. Lin. 1991. Strategies for stocking Nile tilapia (*Oreochromis niloticus*) in fertilized ponds. World Aqauculture Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Korstad, J., R. Mangual and R. Couch. 1991. Performance of hybrid tilapia fed a commercial ration vs algae. World Aqaucultre Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Lester, L.J., T.A. Abella, M.S. Palada and H.J. Keus. 1988. Genetic variation in size and sexual maturation of *Oreochromis niloticus* under hapa and cage culture conditions. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedintgs: 15. International Center for Living Aquatic Resources Management. Manila, Philippines.

McGreachin, R.B., R.I. Wicklund, B.L. Olla and J.R. Winton. 1987. Growth of *Tilapia aurea* in seawater cages. J. World Aquaculture Society 18:31-34.

McNabb, C.D., C.F. Knud-Hansen, T.R. Batterson and K. Jayen. 1991. A systematic approach to maximizing nutrient efficiency and growth of Nile tilapia (*Oreochromis niloticus*) under semi-intensive pond culture. World Aqaucultre Society Annual Meeting: 22. World Aquaculture Society. Baton Rouge, Louisiana, USA.

Meriwether, F.H. II, E.D. Scura and W.Y. Okamura. 1984. Cage culture of red tilapia in prawn and shrimp ponds. Journal of the World Mariculture Society 15:254-265.

Muthukumarana, G. and D.E.M. Weerakoon. 1986. Stocking density and diet of *Oreochromis niloticus* in cages in manmade lakes in Sri Lanka. In: J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds). The First Asian Fisheries Forum. Asian Fisheries Society. Manila, Philippines.

Ofori, J.K. 1988. The effect of predation by *Lates niloticus* on over-population and stunting in mixed sex culture of tilapia species in ponds. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedintgs: 15. International Center for Living Aquatic Resources Management. Manila, Philippines.

Paessun, M.A. and R. Allison. 1984. Maximizing tilapia production in recirculating systems by sequential rearing. Aquaculture 42:185-189.

Peralta, M. and D.R. Teichert-Coddington. 1989. Comparative production of *Colossoma macropomum* and *Tilapia nilotica* in Panama. Journal of the World Aquaculture Society 20:236-239.

Rakocy, J.E. 1989. Tank Culture of Tilapia. SRAC Publication: 282. Southern Regional Aquaculture Center. USA.

Rakocy, J. E. 1990. A recirculating system for tilapia culture and vegetable hydroponics. In: R. Oneal Smitherman and D. Tave (eds). Proceedings of the Auburn Symposium on Fisheries and Aquaculture. Auburn University. Auburn, Alabama, U.S.A.

Rouse, D.B., G.O. El Naggar and M.A. Mulla. 1987. Effects of stocking size and density of tilapia on *Macrobrachium rosenbergii* in polyculture. Journal of the World Aquaculture Society 18:57-60.

Stickney, R.R. 1979. Principles of Warmwater Aquaculture. Wiley-Interscience. New York, USA.

Stickney, R.R. 1985. Production of caged channel catfish in an Illinois surface mine lake. Journal of the World Mariculture Society 16:32-39.

Verani, J.R., M. de A. Marins, S.B. Da Silva and A.C. Sobrinho. 1983. Populational control in intensive fish culture associating *Oreochromis* (*Sarotherodon*) *niloticus* with the natural predator *Cichla ocellaris*: quantitative analysis. In: L. Fishelson and Z. Yaron (compilers). International Symposium on Tilapia in Aquaculture. Tel Aviv University, Israel.

Whitis, G.N. 1989. Growing Caged Tilapia Without Feed in Catfish Ponds. Alabama Cooperative Extension Service Timely Information: March, 1989. Alabama Cooperative Extension Service. Auburn, Alabama, USA.

Integration

Little, D. and J. Muir. 1987. Integrated Warmwater Aquaculture. Institute of Aquaculture. Stirling, Scotland.

Mathias, J.A., A.T. Charles and H. Baotong (eds). Integrated fish farming. CRC Press, Boca Raton, Florida, USA.

Pullin, R.S.V. and Z. Shehadeh (eds). 1980. Integrated agriculture-aquaculture farming systems. ICLARM Conference Proceedings 4, International Center for Living Aquatic Resources Management, Manila, Philippines.

Sedgwick, S.D. 1985. Trout Farming Handbook. Fishing News Books, Ltd. Farnham, Surrey, UK.

Symoens, J.-J. and J.-C. Micha. 1995. The management of integrated freshwater agro-piscicultural ecosystems in tropical areas. Technical Center for Agricultural and Rural Cooperation, Wageningen, The Netherlands.

Parasites and Diseases

Amlacher, E. 1970. Textbook of fish diseases. TFH Publications, Neptune City, New Jersey, USA.

Bowser, P.R. and J.K. Buttner. 1991. General Fish Health Management. NRAC Bulletin: 111. Northeast Regional Aquaculture Center. University of Massachusetts at Dartmouth. North Dartmouth, Massachusetts, USA.

Kabata, Z. 1985. Parasites and diseases of fish cultured in the tropics. Taylor & Francis, London, UK.

Weeds

Applied Biochemists, Inc. 1979. How to Identify and Control Water Weeds and Algae. Applied Biochemists, Inc. Mequon, Wisconsin, USA.

Whitwell, T. and D.R. Bayne. No Date. Weed Control in Lakes and Farm Ponds. Alabama Cooperative Extension Service Circular: ANR-48. Alabama Cooperative Extension Service. Auburn, Alabama, USA.

Hatchery Management

Armitage, A.T.C., J.D. Balarin and R.D. Haller. 1988. The design of a tilapia grader for intensive tank systems. International Symposium on Tilapia in Aquaculture: 2 (abstracts). International Center for Living Aquatic Resources Management. Manila, Philippines.

Balarin, J.D. and J.P. Hatton. 1979. Tilapia: A Guide to Their Biology and Culture in Africa. University of Stirling. Stirling, Scotland.

Dexter, P.A. and R.G. Werner. 1992. Energetics of larval rainbow smelt. NYAFS Annual Meeting: 1992. New York State Chapter/American Fisheries Society.

Guerrero, R.D., III. 1982. Control of tilapia reproduction. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds) The Biology and Culture of Tilapias. ICLARM Conference Proceedings: 7. International Center for Living Aquatic Resources Management. Manila, Philippines.

Hepher, B. and Y. Pruginin. 1981. Commercial Fish Farming with Special Reference to Fish Culture in Israel. Wiley-Interscience. New York, USA.

Hutabarat, J., L. Syarani and M.A.K. Smith. 1986. The use of freshwater hyacinth *Eichhornia crassipes* in cage culture in Lake Rawa Pening, Central Java. In: J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds). The First Asian Fisheries Forum. Asian Fisheries Society. Manila, Philippines.

Jalabert, B. and Y. Zohar. 1988. Reproductive physiology in Cichlid fishes, with particular reference to *Tilapia* and *Sarotherodon*. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds). The Biology and Culture of Tilapias. ICLARM Conference Proceedings: 7. International Center for Living Aquatic Resources Management. Manila, Philippines.

Jhingran, V.G. and R.S.V. Pullin. 1985. A Hatchery Manual for the Common, Chinese and Indian major carps. ICLARM Studies and Reviews: 11. International Center for Living Aquatic Resources Management, Manila, Philippines.

Munro, A.D. 1990. Tropical freshwater fish. In: Munro, A.D., A.P. Scott and T.J. Lam (eds). Reproductive Seasonality in Teleosts: Environmental Influences. CRC Press. Boca Raton, Florida, USA.

Shelton, W.L., K. D. Hopkins and G.L. Jensen. 1978. Use of hormones to produce monosex tilapia for aquaculture. In: R.O. Smitherman, W.L. Shelton and J.H. Grover (eds.). Symposium on Culture of Exotic Fishes. American Fisheries Society.

Transport

Brown, E.E. and J.B. Gratzek. 1980. Fish farming handbook. AVI Publishing, Westport, Connecticut, USA.

Frose, R. 1985. Improved fish transport in plastic bags. ICLARM Newsletter Oct, 1985:8-9.

McLarney, W. 1984. The freshwater aquaculture bok\ok. Hartley & Marks, Point Roberts, Washington, USA.