FINAL TECHNICAL REPORT

Development of integrated aquaculture-agriculture systems for small-scale farmers in the forest margins of Cameroon (NRE9800 605/522/003).

Implementing Agency: WorldFish Center (formerly ICLARM)

Collaborators: International Institute of Tropical Agriculture (IITA), Institut de Recherche Agricole pour le Développement de Cameroun (IRAD), Ministère de l'Elevage, des Pêches et des Industries Animales de Cameroun (MINEPIA).

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List of Acronyms and Abbreviations

ADAF	Appropriate Development for Africa Foundation (local NGO)
APDRA	Association Pisciculture et Développement Rural en Afrique Tropicale
ASB	Alternatives to Slash & Burn Agriculture Program of IITA.
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (de France)
FAO	Food & Agriculture Organization of the United Nations
FSRP	Farmer-Scientist Research Partnership (participatory research paradigm)
IAA	Integrated Agriculture-Aquaculture
ICLARM	International Center for Living Aquatic Resources Management (WorldFish)
IITA	International Institute of Tropical Agriculture
IRAD	Institut de Recherche Agricole pour le Développement (de Cameroun)
ISTOM	Ecole supérieure d'Agro-Economie Internationale (Cergy-Pontoise, France)
MINEPIA	Ministère de l'Elevage, des Pêches et des Industries Animales (de Cameroun)
MINREST	Ministry of Research and Technology
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
PARC	Participatory Aquaculture Research Centre (part of Yaoundé Fish Station)
PNVRA	Programme Nationale de Vulgarisation et Recherche Agricole
RESTORE	Research Tool for Natural Resource Management, Monitoring & Evaluation
RET	Research-Extension Team (IRAD coordinator + 3 MINEPIA technicians)
SEAPB	Service d'Etudes et d'Appui aux Populations a la Base (local NGO)
SOWEDA	Southwest Development Agency (a project of African Development Bank)
SSA	Sub-Saharan Africa

EXECUTIVE SUMMARY

WorldFish Center (formerly ICLARM) aquaculture experts, IITA economists, IRAD researchers and MINEPIA technicians formed a Research-Extension Team (RET) to undertake action research on the importance of markets in driving aquaculture intensification. The primary objective was to understand the processes that create increased opportunities for small-scale farmers to improve their livelihoods while decreasing pressure on natural resources in the forest margins of Central Cameroon. In addition, the costs and benefits of participatory research and increased availability of cultured fish for urban markets were documented. Over five years, seven cycles of participatory research were conducted between the RET and a group of 100 farmers from four typical central Cameroonian villages, selected over a range of market access and population density domains. To increase the range of collaborative interactions and expand project impacts beyond the target villages, a network of NGOs was created to disseminate information and a Research Committee was established to manage 32 ancillary research projects through a competitive grants facility.

The project sought to intervene as a development actor at a number of levels. In terms of policy, the project worked with local and international agencies to define, describe and institutionalise a Strategic Framework for Aquaculture Development. The model was first applied in Cameroon, but through collaboration with FAO is now being adapted to a number of other countries within the region.

At ground level, the RET worked directly with farmers and non-governmental organizations (NGO) to disseminate information and improve human resource capacity in terms of aquaculture technology and delivery mechanisms. A number of training courses were undertaken to reinforce basic aquaculture technology as well as develop new research and analytical tools for use by the national agricultural research system (NARS). An email information dissemination network was established among local aquaculture development agents and regional aquatic resource scientists and managers.

Over 40 reports, 11 technical bulletins and a number of radio, television and newspaper items were produced and disseminated locally, regionally and internationally through the primary scientific literature, popular media, trade journals, information networks and participation by project staff in 33 seminars/conferences.

The findings of the project were directed at several key corollaries of the Sustainable Livelihoods development paradigm and the utility of participatory research in engendering farming systems intensification:

Changes in Fish Production & Number of Fish Farmers: Productivity of small-scale aquaculture in the target areas increased over the project period from 498 kg/ha to 2525 kg/ha. The number of active fish farmers in the target areas increased from 40 to 137, among whom cash returns from aquaculture increased by 16 times. Farmers not directly participating in project activities also benefited such that 262 small-scale farmers with 870 ponds are currently producing 14.4 tons per annum (£30,000 wholesale) for the Yaoundé market. In addition, an average of 50 kg/family/9 months and 8 kg/family/9 months in periurban and rural areas, respectively, are consumed by the farm family.

Changes on Farm / Periurban Vs Rural: Farming systems diversification through the integration of aquaculture significantly increased the productivity, intensity of production and profitability of small-scale farms in periurban areas, but not in rural areas. Among farmers with good market access, net profits rose from cfa180,000 to cfa770,000 with increases in fish pond income from cfa49,000 up to cfa870,000 over the project period. The amount of

fish retained for consumption by the farming family was higher in periurban areas (26% Vs 17% in rural areas) where freezers were available to store fish for later use.

Cost of FSRP: Provision of participatory research services to the original 50 rural farmers cost an average of £26,900 per year in salaries, equipment, vehicle operation/depreciation. In periurban areas where transportation was less expensive, costs averaged £7,140 per 50 farmers per year. Calculated on a per active farmer basis (within the target villages at the end of the study) the costs come to £317 and £130 per farmer per year, respectively for rural and periurban farmers. In terms of fish supplied to the market, FSRP support cost slightly more than the retail value of the fish produced, £170,000 Vs £140,000. Nearly 80% of these costs were incurred in providing services to rural farmers. If only existing periurban farms are targeted, £10,000 worth of technical support could produce revenues of at least £51,000 on sales of 26 tons of fish per annum.

In conclusion, this research has shown that the provision of high-quality technical advice to farmers with market access can have a strong positive impact on farm productivity and profitability among small and medium-scale farmers. In areas with good market access, these impacts are quickly translated into improved cash flow and household nutrition. In areas with little or no access to markets, the number of fishponds and fish farmers can be increased and pond productivity can be improved, increasing local food supplies. However, economic impacts are not clearly visible in the short-term. Comparison between response to RET intervention on periurban and rural farms shows that, if market access by rural producers can be improved, realistic cash incentives and thus improved cash flow and sectoral growth are likely. Following pilot trials under the project, an NGO-led effort to facilitate market access and the development of a sustainable rural fish marketing business plan is continuing with RET support.

BACKGROUND

The tropical rain forests of Central Africa are under threat from slash and burn agriculture fuelled by increasing poverty and demand for land by rapidly growing rural populations. The diversification of farming systems to take advantage of new marketing and food production opportunities is one of the commonly observed responses of households facing increasing resource pressure. This phenomenon has been well documented in the northern portion of the Forest Margins Benchmark of southern Cameroon, where IITA coordinates an inter-centre initiative aimed at sustainable management of the humid forests. The Forest Margins Benchmark area has been extensively characterized in terms of land use strategy and development potential. Farming in the northern portion of the benchmark has diversified in response to a combination of both population pressure and market access to Yaoundé, whose 1 million residents provide many new market opportunities. The diversification of farming systems in this area has mainly focused on the production of high value horticultural commodities with intensive input use. Among factors identified as important in the diversification/intensification process are shortening fallow periods, roads, vehicle traffic, storage facilities, market information, and access to inputs. In 1998, IITA farming system characterization identified integrated agriculture-aquaculture (IAA) as a possible livelihoods strategy for Cameroonian smallholder farmers.

Integrated Aquaculture

In Ghana, Malawi, Tanzania and Zambia, aquaculture integrated into an existing agricultural system has been shown to substantially increase fish production, overall farm productivity and produce up to 6-fold improvements in profitability. In Malawi, average fish productivity of integrated smallholdings is about 1500 kg/ha/yr compared to an average of about 900 kg/ha/yr for non-integrated fish farms. The integrated pond-vegetable garden is the economic engine on these farms, contributing on average 72% of annual cash income. On a per unit area basis, the vegetable garden/pond resource system generates almost \$14 per $100m^2$ per year compared with \$1 and \$2 for the staple maize crop and homestead (non-farming activities), respectively. By most estimates, Malawi is a low potential country for aquaculture due to generally low and highly variable rainfall. Also, high population densities, high demand for fish and lack of commercialisation of agriculture have resulted from very poor market infrastructure and access. The potential of IAA in countries with more water and better-developed markets, such as Cameroon, may be much higher.

With rapid growth of urban markets (5 to 7% in Cameroon) farmers are seeking new ways of investing their labour in productive assets. In Central Province, fish is the most important source of animal protein in the diets of both rural and urban households and its importance increases among the poor. With a 50% decrease in availability of fish per capita over the last 10 years, demand and prices for fish are extremely high, creating new opportunities that could be exploited by market-driven, small-scale fish farmers.

Fish Farming in Cameroon

The history of aquaculture in Cameroon is similar to that in many other African countries. Introduced in the late 1940's, more than 10,000 ponds had been built by 1962. Many of these were subsequently abandoned. These failures were largely the result of:

- focusing on fish in isolation from other farming activities and related community structures. Projects did not take into consideration the full range of opportunities and constraints faced by smallholding farmers.
- approaches that relied on rigid technology packages rather than the application of flexible principles.
- reliance on technologies developed on experiment stations that were not applicable to prevailing agronomic or economic conditions at the farm level.
- a top-down relationship between extension and farmers that effectively prevented joint learning.
- poorly trained extension personnel who neither understood the technologies they were promoting nor could communicate effectively with smallholders.

The systematic evaluation of such experiences led the Government of Cameroon in 2000 to seek a partnership with the WorldFish Center (then known as ICLARM) aimed at establishing a farmer-participatory approach to aquaculture outreach and development. WorldFish brought to the partnership a background in successful participatory research and development. The two government agencies dealing with aquaculture, the Ministere de l'Elévage, des Pêches et des Industries Animales (MINEPIA) and the Institut de Recherche Agricole pour le Développment (IRAD) contributed considerable knowledge on local aquaculture practice, local socio-cultural norms and many years of practical experience working at the farm and villages levels to promote fish farming.

The northern portion of the Forest Margins Benchmark is characterized by wide variations in rural population densities, rural infrastructure, access to farm inputs, intensification of agriculture and contact with market agents. We took advantage of this variation to investigate the hypothesis that increases in the institutional development of markets (for both output sales and input purchases) engenders the intensification of IAA systems. We anticipated a general trend towards higher yields and profits in areas with better markets.

PROJECT PURPOSE

The forest margin benchmark is characteristic of some 1,923,840 km^2 of Africa's largest remaining tropical rainforest. Approaches and technologies which are found useful in this area have the potential to affect the lives of 258 million Africans in the 15 countries in which rain forests still play a role in the national economy. In the last 10 years, availability of fish has declined steadily in these countries (Benin, Cameroon, Central African Republic, Congo-Brazzaville, Congo-Kinshasa, Côte d'Ivoire, Equatorial Guinea, Gabon, Ghana, Guinea, Liberia, Madagascar, Nigeria, Togo, and Uganda) and the magnitude of the shortfall is increasing. In these countries, fish is a major component of animal protein intake, being especially important among the poor. To meet shortfalls, these governments have been forced to import fish at a cos t of $458 million per year (over $27 million in Cameroon alone).

On a continent where an estimated 70% of the population is rural, the potential impact on food security from IAA is enormous. Using very conservative figures, FAO has recently estimated that 31% of sub-Saharan Africa (parts of 40 countries, 9.2 million km^2) is suitable for small-scale integrated fish farming. If production figures from relatively recent development projects (1300-2300 kg/ha/yr) are used, 580,000 tons, or 35% of Africa's increased fish need up to the year 2010, could be met by small-scale fish farmers on only 0.5% of the total area potentially available.

The project's focus on smallholder farming systems and technologies accessible by asset-poor households was designed to engender a significant impact on poverty, compared to projects that concentrate on fish production and consequently engage the wealthier members of the community. In the more densely populated portions of the benchmark, valley bottoms are the least utilized lands and offer households with relatively poor land endowments a chance to build the assets needed to provide a pathway out of poverty and, once established in the family, these resources become heritable. It is not surprising that the majority of fish farmers are, in fact, smallholding farmers rather than investors with outside sources of income. The major investment in creating small, integrated fishponds is the farmer's labor. Access to valley bottoms has been traditionally granted to potential users based on need and interest to develop them. Little if any cash outlay is required, and therefore capital and land poor households were expected to benefit.

Poverty is associated in the region with market access and market opportunities, increasing in remoter areas where farmers lack good market access. In these areas, although there may still be adequate land for upland farming, because of the poor state of rural roads and high transportation costs, farmers are effectively barred from staple food markets. Farmers can spend more than half the unit price of the staple commodity (e.g. cassava) in getting it to market. Because of this, staple food production is largely subsistence and potentially large food surpluses are under-exploited. By converting these surpluses into fish food and subsequently fish, the farmer can produce a high value, high protein commodity (e.g. per unit value 20 to 30 times that of cassava) that has a ready and elastic market.

Another anticipated livelihood impact was improved nutrition for both fish producing households and from contributions to national fish stocks. A household consumption study among urban households in Yaoundé has revealed that the households in the poorest quintile spend 27% of their budgets on fish (versus 21% for meats) and have an income elasticity >1. This implies that poor households will spend proportionally more of an additional franc on fish than on other food budget items. The study also revealed that 39% of the protein intake for these households was of fish.

The main purpose of the Development of Integrated Aquaculture-Agriculture Systems for Small-scale Farmers in the Forest Margins of Cameroon project was to develop the knowledge base necessary to:

- Capitalize upon opportunities to improve rural and periurban livelihoods through the use of integrated aquaculture technology.
- Create income and food generating alternatives to expanded slash and burn agriculture.
- Develop marketing strategies that can realize the financial incentives necessary to drive rural economic growth.
- Influence policy changes that favour the growth of sustainable, integrated farming systems, especially those which are aquaculture-driven.

RESEARCH ACTIVITIES

There were three questions of strategic importance which we sought to answer directly through this project:

- How does market access and structure affect aquaculture development?
- Is participatory research a suitable tool for increasing farm-level knowledge and overall human resource capacity under a range of contexts?
- What are the productivity, economic and social impacts of IAA in forest margins and are they sufficient to justify forest conservation?

1. **H_0: Market access/infrastructure affects adoption and growth of IAA:** Theory indicates that as market access increases (for both fish sales and input purchases) the intensification of IAA systems also increases as measured by the number of innovations and quantity of inputs used which in turn should be reflected in higher yields and profits. An alternative hypothesis is that remote households that have difficulty in marketing crop surpluses will intensify aquaculture production via feeding of crop surpluses as a means of converting low value bulky products into high value fish, which are more easily marketed based on value to weight ratio. A third possibility is that, as market isolation increases, home consumption of fish increases. Detailed data on markets and marketing of inputs, fish and fish products were collected and fed immediately into the FSRP process to facilitate selection of participatory research topics on, for example, economically optimal use of inputs or the potential for improved fish preservation. The role of markets in aquaculture development could provide valuable guidance to policy makers and project planners in determining where and how aquaculture support funds should be allocated and focused.

2. **H_0: The FSRP approach is responsive to a wide range of constraints and opportunities and can promote the growth of aquaculture in forest margins:** Having been successfully employed in Malawi, the FSRP requires an assessment of its robustness prior to being more widely promulgated. A principles-based approach to technological intervention and a collaborative relationship between farmers and TDT outreach have been key features of successful aquaculture development in many regions. These are also the guiding principles behind the FSRP. A participatory and systematic approach to problem solving can engender joint learning by farmers and researchers leading to mutual understanding of constraints and realistic evaluation of opportunities. Improved human resources form a core of practical expertise that can be applied broadly to problems facing aquaculture development at a variety of levels and intensities.

3. **H_0: IAA affects economic and productive function on smallholdings in the forest margins:** Improvements in farming systems that render them more profitable and productive can alter the internal relationships among farming enterprises as well as the external relationships between the farm and its social and ecological environment. Improved efficiency of the farm resource base can reduce pressure on forests and other natural resources. Conversely, land use changes and revaluation of resources and opportunities can lead to conflict over tenure and access to benefits. Gender roles in fish production and marketing tend to be rigid. Characterization, documentation and optimisation of resource use and marketing strategies directly benefit the many women who participate in the fisheries economy.

4. **H_0: IAA sustainability is influenced by the knowledge base on tropical fish biology and ecology:** Designing pond production systems based on knowledge of the biophysical function of the specific system into which modifications are to be introduced will inevitably improve the quality of management. The development of indigenous species for aquaculture will increase the value of biodiversity and create a strong motive for its conservation.

The project worked in two modes: the first was to undertake a series of participatory research trials to establish the basic technology and marketing strategies for commercial aquaculture. To capture impact and quantify results, a comprehensive household and farming systems analysis was undertaken before and again after the approximately five years of research. These studies were undertaken among 100 farmers (25 per village) in a matrix of typical Forest Margins Benchmark villages based on previously collected data on market access and population density by IITA[1]:

Village	Characteristics (Market Access; Pop Density)	Distance to Yaoundé	Inhabitants per km^2	Population	Cost per Person to Yaoundé
Soa	High Access; High Density	11.5 km	290	100 000	350
Mbankomo	High Access; Low Density	19.0 km	54	6 000	500
Yemssoa	Low Access; High Density	52 km	101	2 500	1000
Akono	Low Access; Low Density	60 km	54	3 000	1400

Once the baseline dataset was completed, a series of farmer participatory research trials were conducted. Each of these trials involved a subset of the 100 farmers experiencing a particular problem. Topics for research were selected through group meetings and discussion, coupled to site visits and problem analysis:

Pond Construction: water depth and water exchange rate were tested among a group of 67 farmers. Data on pond configuration were regressed against yields to demonstrate the importance of proper pond construction.

Production Systems: composting structures, compost materials and supplemental feeding strategies were tested among all the farmers. Analysis of variance was used to analyse the differences in yield resulting from the use of weeds (*Tithonia, Chromolaena*) in compost, the size of the compost crib (1.0 Vs 10% of pond surface area) and formulated diets Vs compost demonstrated the important role pond fertility plays in fish growth in extensive/semi-intensive systems.

[1] Gockowski, J. & M. Ndoumbé. 1999. An analysis of horticultural production and marketing systems in the Forest Margins Ecoregional Benchmark of Southern Cameroon. Resource & Crop Management Research Monographs 27, International Institute of Tropical Agriculture, Ibadan, Nigeria.

Hatchery Systems: a prototype hatchery was developed by field technicians considering constraints faced by local farmers, and tested on four farms (one in each village).

Marketing Strategies: The final trial was a test of a collective marketing strategy developed by SEAPB, a local NGO specializing in group dynamics. This involved the NGO managing the purchase of fingerlings (on credit), technical training in basic catfish farming, collective harvest and joint marketing between the NGO and 32 members of local farmer groups.

Each participatory research project was summarized in a group seminar in which all participating and non-participating farmers were brought together to present and discuss their results. For each project, at least one technical bulletin was produced to reinforce and document the lesson.

In addition to the larger scale trials, there were a number of smaller topics in sociology, economics, biology and ecology that we addressed through a series of sponsored research projects. Most of these were also carried out in a farmer participatory mode, giving exposure to concepts of action research to a number of local experts and development agents. These projects were administered by a Research Committee comprised of senior representatives of MINEPIA, IRAD, WorldFish, IITA and CEPID (a local NGO). Research Committee meetings were open to the public and many interested parties contributed ideas and comments on the various projects:

Topic	Principal Investigator(s)	Affiliation
Evaluation of the market for and marketing of fresh fish in Yaoundé	Christopher Cho Achu (economist), Dieu ne Dort Wandji (resch technician)	Positive Vision Consulting Group
Fish Marketing Strategies for Yaoundé	Nelly Soua (econ), B. Souk (NGO)	SEAPB
Socioecon. Review of Aquaculture in W Province	Victor Pouomogne (aquaculturist)	IRAD-Foumban
Agricultural Investment Options in SW	Samuel Ajonina (aquacult. economist)	SDA Church
Control of Larval Mortality in *Clarias gariepinus*	Steve Sulem (aquaculturist)	IRAD-Yaoundé
Socioeconomic Impacts of Chemical Fishing	Pierre Nna Abo'o (fisheries biologist)	MINEPIA
Contamination of Fishes from Periurban Wetlands	Joseph Demanou (toxicologist)	Univ. of Yaoundé
Reproductive & Dietary Seasonality of River Fish	David Nguenga (fish biologist)	IRAD-Foumban
Economic Efficiency of Aquaculture in Yaoundé	Jeshma Bakwowi (economist)	Independent
Natural Reproduction of *Clarias gariepinus*	Charles Gabche (Fisheries Biologist)	IRAD-Batoke
Economic Evaluation of Pre-Rearing *H. niloticus*	Pierre Nna Abo'o (Aquaculturist)	MINEPIA
Survey of Local NGO Capacity in Aquaculture	Pierre Abé (development agent)	Independent
Marketing Freshwater Fish in SW Province	Samuel Ajonina (Aq. Economist)	SDA
Economic evaluation of hand-sexing tilapia	Desire Etaba (hatchery operator)	Independent
Use of papaya seeds to sterilize tilapia	Desire Etabe (hatchery operator)	Independent
Fisheries Information Management Systems for the Sanaga and Nyong Rivers	François Tiotsop (fisheries economist)	MINEPIA
Fisheries characterization on the Sanaga River	Rodrigue Yossa (technician)	Univ. of Dschang
Development of ornamental fish food	Thèrese Mbongo (technician)	Univ. of Dschang
Labor Allocation of Women Smallholders	Anaïs Bode (women in development)	ISTOM
Marketing Freshwater Fish in SW Province	Samuel Ajonina (aquaculture econ.)	SDA Church
Economic Comparison of Clarias Hatcheries	Steve Sulem (aquaculturist)	IRAD-Yaoundé
Natural Reproduction of *Clarias gariepinus*	Bertin Sahmo (fisheries biologist)	MINEPIA-Limbe
Comparison of New Tilapia Stocks	Desiré Etaba (aquaculturist)	Independent
Feasibility of Local Marketing of Ornamental fish	Pierre Nna Abo'o (fisheries biologist)	MINEPIA
Least cost feed formulations for SSA	Melanie Hauber (student)	Univ. of Kassel
Artificial Reproduction of Ornamental Fishes	Pius & Benedicta Oben (aquaculturists)	Univ. of Buea
Optimization of Agricultural Fishpond Composts	Rodrigue Yossa (rsch tech, student)	Univ. of Dschang
Economic Efficiency of Catfish Feeds	Thèrese Mbongo (rsch tech, student)	Univ. of Dschang
Development of a collective marketing aquaculture business plan	Nelly Soua (econ.), Firmin Teteo (aqua) Bernard Souk (development agent)	IITA, MINEPIA, SEAPB
FSRP Research to Develop Local Catfish Hatchery Technology	Steve Sulem & David Nguenga (aquaculturists)	IRAD

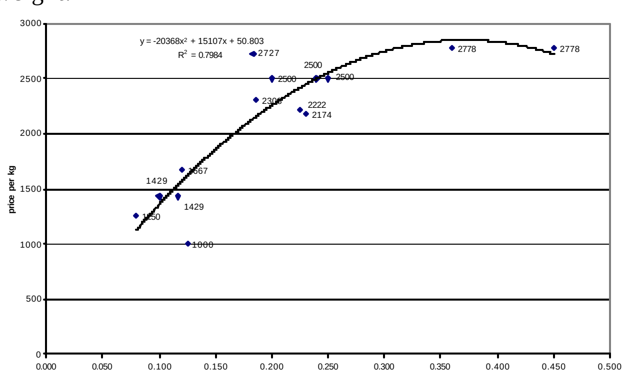
To support these research activities, the Yaoundé municipal fish culture station, originally constructed in 1952 by the French colonial administration, was modestly renovated to provide fingerlings needed for participatory research. The station has now been renamed the Participatory Aquaculture Research Center (PARC). Training was provided to 10 government extension technicians, three of whom received intensive orientation on participatory research methodology through cross-site visits to Malawi (where the WorldFish participatory research paradigm was developed). These trips also included training in the RESTORE computer software used to document farming systems evolution. In addition, for the three principal project technicians, the project sponsored correspondence BSc equivalency degrees in aquaculture from the University of Dschang. Three other technicians who came to the project as graduate students and worked on both the main and sponsored research projects, completed their MSc degrees and have now been accepted into European graduate programs at Ghent (Belgium), Liège (Belgium) and Nantes (France).

OUTPUTS

All project research objectives were achieved. In addition, participation in aquaculture and fish production in the target areas increased substantially. Average standing stock at harvest (6-9 mos) rose over the project period from 498 kg/ha to 2525 kg/ha. The number of active fish farmers in the target areas has also increased, from 15 up to 137, among whom cash returns from aquaculture increased by 16 times. Farmers who were not directly participating in project activities also benefited with the result that there are now at least 262 smallscale farmers with 870 ponds producing 14.4 tons per annum (worth some £30,000) of tilapia and catfish for home consumption and/or sale into the Yaoundé market. Within the Central, Southern and Western Provinces, information has been regularly delivered to an estimated (by our NGO partners) 2000 other farmers through technical bulletins, farmer field days, seminars, television, radio, newspaper and a range of NGO sponsored activities. Following the lead of a local NGO partner, a structure and business plan are now in place for follow on work in collective production and marketing, with hoped-for support from local donors and government. Summaries of findings for the main research hypotheses:

1. Market Access Affects Adoption and Growth of IAA: Understanding the structure of the Yaoundé market was critical to the design of a marketing strategy. Prices, seasonality, wholesale and retail chains were analysed. A limited number of women "buyam-sellums" dominate the fresh fish market, defending their territory robustly. Based on price data and the need for maximum production efficiency, the target size for harvested fish was 350 g(Figure 1). Marketing is complicated by a shortage of cash in the market, with many participants still relying heavily on barter. As cacao remains the major cash crop, fish harvests are timed to coincide with availability of cash (December, following cacao sales) as well as demand peaks, such as Christmas and Easter.

Figure 1. Market prices for live catfish as a function of average weight.



Among many development

planners, market failures (e.g., low and/or non-cash prices paid to farmers thus creating disincentives to production) are posited to lie chiefly behind the failure of aquaculture to develop beyond a subsistence scale. In Cameroon, the positive impact of market incentives on the scale and intensity of fish production was demonstrated through a comparative analysis of two groups of fish producers differentiated by the location of their harvest market in either the periurban or rural zones of southern Cameroon (Table 1). In the periurban domain, prices were 48% higher, the number of buyers was three times greater, and the average purchase per customer was nearly double that of the rural domain. In response to these structural differences, producers in the periurban domain sold 300% more fish, were 72% more productive, and were 11 times the production scale of rural producers. These data are evidence of market failures in fingerling and feed supply, which are major impediments to growth. There appears to be an urgent need to connect rural producers to urban markets in order to foster the growth of aquaculture in sub-Saharan Africa.

Table 1. Differences in the scale and intensity of production between rural and peri-urban fish farmers in southern Cameroon (65 farms).

	Type of Producers		
Variable	**Peri-urban**	**Rural**	**P**
Fish distributed per harvest (kg)	196 ± 111	45.8 ± 19	0.0104
Yield per hectare (kg)	2,060 ± 940	1,200 ± 475	0.0194
Pond area in production (m^2)	6,260 ± 9,790	534 ± 195	0.0711
Estimated total annual production (kg yr^{-1})	1,133 ± 1,431	64.6 ± 43.2	0.036
Fingerling stocking density m^{-2}	1.56 ± 0.876	0.603 ± 0.655	0.00702
Use of purchased feed stocks	75% ± 0.463	23% ± 0.417	0.0259

A key difference between rural and periurban producers was also noted in the number and type of adopters. Rural producers tended to be more dependant upon groups, while periurban farmers were more likely to work alone (Table 2). The main reason given for this by farmers was that in rural areas pond construction, in particular, is heavy work and requires a group effort to succeed. In periurban areas, farmers are reluctant to take on social relationships with non-family members and prefer to hire labour as necessary.

Table 2. Evolution of participation in aquaculture and the importance of groups across sites.

	Akono (low pop; low access)	**Mbankomo** (low pop; high access	**Yemssoa** (high pop; low access)	**Soa** (high pop; high access
Active farmers (12/00)	4 (9 ponds)	3 (5 ponds)	5 (9 ponds)	3 (5 ponds)
Active farmers (07/05)	36 (93 ponds)	22 (76 ponds)	49 (86 ponds)	30 (57 ponds)
Ancillary adopters*	8	3	24	20
Farmers active in groups	100% (2 groups)	14% (1 group)	100% (5 groups)	0%

* Farmers in the target villages not directly associated with the project but benefiting from the increased availability of information.

In addition, the number of new farmers and ponds expanded at very similar rates in both rural and periurban zones, despite the above evidence that profitability was higher in the latter. To understand this seeming contradiction, one needs to look at the role a fishpond typically plays in Cameroonian farming systems. Field observations and discussion with farmers revealed that, in rural areas, aquaculture is normally viewed as a secondary activity, after staple crop production (cassava & plantains). A fishpond is similar to chickens, goats, vegetable production and a number of crops grown primarily for cash (e.g., tobacco, cotton, coffee, tea, cacao). Investments for such systems are low, permitting many farmers to take advantage of correspondingly low, but fairly reliable yields. Rather than making tradeoffs and taking risks by allocating all of the farm resources to the one or two most profitable enterprises and keeping the money in the bank to buy food as needed, rural small-scale farmers tend to diversify by growing a number of crops simultaneously (often in mixed plots), thereby spreading the food production capacity of the farm over the entire year (see Figure 4, and associated discussion, below). This also has the effect of lowering overall risk of crop failure and subsequent famine.

A key objective of farmers in producing fish is to supply high quality animal protein to the household. In both rural and periurban harvests, a substantial portion of the fish was consumed by the household (Table 3). However, most rural households, lacking refrigeration, are limited in the share of the harvest consumed to a maximum of 29 kg; among periurban households where a higher proportion have freezer capacity, the maximum amount of fish intended for home consumption was 233 kg. On the other hand, statistically similar proportions of fish were given away by the household among rural and peri-urban farmers: 24% versus 28%, respectively (although, in effect, this was generally some 30% higher in rural areas where many so-called “sales” result only in some later exchange of goods or labour, rather than cash).

Table 3. Differences in structural and price parameters between rural and peri-urban harvest markets in southern Cameroon (84 farms).

	Type of harvest market		
Variable	**Peri-urban**	**Rural**	**One-tail T-test**
Number of buyers in market	25.4 ± 8.96	8.31 ± 7.32	0.0004
Average quantity per sale (kg)	4.12 ± 3.47	2.4 ± 0.76	0.166
Total quantity marketed per harvest (kg)	89.9 ± 48.7	28.2 ± 23.5	0.0127
Total quantity given as gifts (kg)	55.7 ± 41.2	11.4 ± 9.3	0.0458
Total quantity consumed by household (kg)	50.3 ± 89.6	8.3 ± 6.8	0.302
Catfish price (FCFA kg-1)	2,583 ± 376	1,636 ± 354	0.00002
Tilapia price (FCFA kg^{-1})	1,833 ± 408	1,054 ± 258	0.00004
Mean price all species (FCFA kg^{-1})	1,908 ± 570	1,290 ± 386	0.00533

Due to social pressures to sell fish locally or give them away, and in light of the difficulties associated with moving fish to a wealthier (urban) market, selling produce for cash is often not a realistic option for rural farmers. To overcome these constraints, collective marketing for rural farmers was tested in the final year of the project. This experiment included 32 farmers and was organized by SEAPB, a local NGO with previous experience in marketing smallscale agricultural products. Although, the longer-term impact of this effort will not be measurable immediately, some preliminary observations were that:

1. Instead of selling 50% of their harvest, farmers in the test group took advantage of the opportunity and sold 100% of their fish for cash.

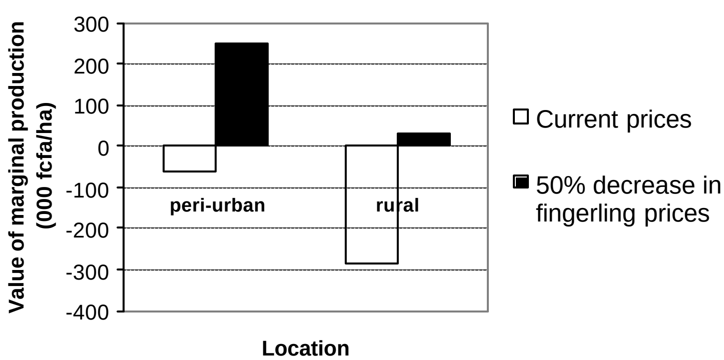
2. Average price received by farmers rose from 1162 cfa/kg (650 – 1500) to 1875 cfa/kg (1200 – 2000, depending upon whether the fish were sold to wholesalers or to restaurants).
3. Number of farmers interested in collective marketing rose from 32 to 60 (within 3 months of harvest).

A follow-on workplan to formalize the previously experimental marketing strategy based on the experiences of 2004/2005 is currently being implemented. The objective of this continued effort is to determine the feasibility and profitability of such a collective marketing scheme.

Another interesting finding of the market research, was that, at the reported prices of catfish and tilapia table fish in rural and urban settings and fingerling prices of cfa 25 and cfa 100 for 5-7g tilapia and catfish fingerlings, the estimated cost of the additional fingerlings (cfa 625 000 ha^{-1}) exceeds the value of the marginal production in both the periurban and the rural domains. If the cost of tilapia and catfish fingerlings were reduced by 50% to 12.5 and cfa 50 per fish, the results change substantially. At this fingerling price, the net marginal benefit becomes positive and equal to cfa 561 000 and cfa 342 000 ha^{-1} for the peri-urban and rural producer, respectively (Figure 2). Thus at current fingerling prices the model suggests that the mean stocking rate exceeds the economically efficient level particularly among rural producers facing substantially lower output prices.

This finding highlights the shortage of fingerling production in southern Cameroon, particularly for catfish, and the high price commanded by the few operating hatcheries in the area. One of the outcomes of an underdeveloped fingerling market is a high rate of *de facto* monoculture of tilapia by producers unable to procure catfish fingerlings. These findings support the need for a focus on the institutional development of fingerling markets especially for catfish and kanga (*Heterotis niloticus*) and the promotion of polyculture. A key element will be the transfer of fish hatchery technology to new producers interested and capable of entering this market.

Figure 2. Net marginal benefit of increasing stocking rates by 1 fingerling m^{-2} in southern Cameroon under two fingerling prices.



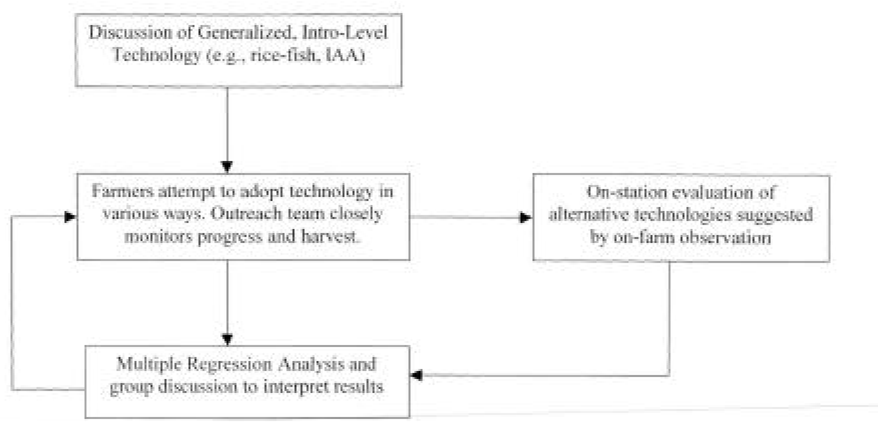
2. Participatory Research can Promote the Growth of Aquaculture: The expansion of aquaculture in the project areas is discussed above (under adoption) and below (under economic impacts) and demonstrates the effectiveness of participatory research in encouraging adoption and intensification. Under this section, the focus will be on the evolution of the Farmer-Scientist Research Partnership (FSRP) participatory research tool based on lessons learned over the course of the project.

The FSRP, like a number of other participatory research tools, relies on a shift in the role that scientists play in the development process (Figure 3). Participatory researchers go into the field, meet farmers, discuss their problems, identify possible starting points for improvement and then screen their ideas through the farmer's knowledge of what might actually work. In general, researchers cannot afford to spend all their time in the field, so from past experience we used a figure of 25% of a scientist's time for the purposes of the Cameroon project. Results of applying the FSRP approach in Cameroon are shown in the section below on economic impacts.

Over the course of the project, we have attempted to streamline the FSRP and focus on the key aspects that make it work:

- A learning attitude on the part of researchers and extension personnel.
- Senior team leadership (i.e., keeping research in contact with farmers and extension agents).

Figure 3. The Farmer-Scientist Research Partnership (FSRP), a participatory research and development tool for encouraging the adoption and intensification of farming systems.



- **Time** to build confidence & trust to overcome development effects.

The first major change was to remove many of the remnants of the farming systems approach that sought to capture visual images of the farm in the form of resource flow diagrams and transects. Farmers didn't seem to get much added value from this extra work and since the data collected could not be easily synthesized, compared and tabulated, the piles of maps and diagrams started to take up a lot of lab space. In addition, the RESTORE software which was developed largely in Asia and which attempts to capture visual images of farming system transformation, turned out to be unwieldy, difficult to apply to Cameroonian farms and not easily amenable to statistical analysis.

The second major modification was to include extension agents. To do this, the role of extension had to be modified from one of interpreting research results and attempting to convince farmers to adopt new technology, to one of working with farmers to incrementally adapt new ideas to an actual farming situation. By setting up trials, carefully documenting the execution of the trials and then analysing together the results, extension agents, farmers and researchers all learn, gain experience and develop a common understanding of farming realities. In fact, in place of research and extension, the process of participatory research may be better termed "outreach" or "facilitation" in as much as the key activity is mutual learning rather than technology transfer.

The third, and most recent, change has been to shift from analysis of variance as a statistical model to multiple regression, and with this from letting farmers choose from a range of established technologies to one of adapting a single generalized technology in innovative ways to a number of farming situations. This change came about primarily as a result of farmers not wanting to be part of treatments that were expected to fail. With a regression model, each farmer can do whatever he or she wants. Careful monitoring of a range of biophysical and management parameters then permits the researchers to retroactively identify the salient features of those farms where production was improved. If there are sufficient replications, regression also helps with the logistical problem of having to get all the ponds stocked and/or harvested at more or less the same time.

Implementing the FSRP is no more expensive than other research and extension strategies, and arguably makes more positive contribution than the Training & Visit (T&V) system currently used by the National Extension Program (PNVRA). In Cameroon, provision of RET participatory research services to the original 50 rural farmers cost an average of £26,900 per year in salaries, equipment, vehicle operation/depreciation. In periurban areas where transportation was less expensive, costs averaged £7,140 per 50 farmers per year. Calculated on a per active farmer basis (within the target villages at the end of the study) the costs come to £317 and £130 per farmer per year, respectively for rural and periurban farmers.

Over all groups, in terms of fish supplied to the market by smallscale farmers, pilot FSRP support cost more the retail value of the fish produced, £170,105 Vs £142,105. This ratio should improve as productivity continues to increase over time (as it has in other places exposed to participatory research approaches), but may pose constraints to projects in their early phases, or private sector ventures to provide technical support services to smallscale farmers. On the other hand, if only the existing periurban farms are targeted, approximately £10,000 worth of technical support could produce revenues of at least £51,000 on sales of 26 tons of fish per annum. The higher profit margins enjoyed by periurban farmers might also enable them to pay for at least a part of the technical services provided by the RET.

3. IAA Affects Economic and Productive Function of Smallholdings: Productivity of smallscale aquaculture in the target areas increased considerably over the project period (Table 4). Average standing stock at harvest (6-9 mos) rose from 498 kg/ha (range: 100 – 900) to 2525 kg/ha (range: 1000 - 6700). The number of active fish farmers in the target areas increased from 40 up to 140 (including new members who replaced some disinterested original members), among whom cash returns from aquaculture increased by 16 times (from 29 up to 473 cfa/m^2). This increase is due to the application of improved management systems engendered by access to technological advice provided by the RET, as evidenced by the decline in productive surface area among the original project farmers from 6.3 ha to 2.8 ha. Secondary adoption (farmer-to-farmer knowledge transfer) and the dissemination of technical materials and media messages have benefited non-target farmers with the result that there are now at least 262 smallscale farmers with 870 ponds[2] producing 14.4 tons per annum (worth some £30,000 on the wholesale market).

[2] Hundreds of prospective and active fish farmers visited the PARC over the course of the project, many of whom purchased fingerlings and/or collected copies of technical brochures. Of the 120 non-targeted farmers interviewed, all had been made aware of the project through contact with targeted farmers or the media and are using at least some of the improved pond construction and management technologies adapted by the RET.

Table 4. Economic indicators of farming systems function among a sample of 96 smallscale farmers in Central Province Cameroon, showing changes between the 1999-2000 and 2004-2005 cropping seasons. Values are inclusive of both cash and estimated non-cash values of products and services.

Village	**IAA?**	**Total Farm Operating Costs**		**Off-Farm Income**		**Non-Ag Income**		**Ag Income**		**Fish Income**		**Net**	
		2000	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**
Akono	Yes	442 325 ±200 954	357 060 ±85 454	73 917 ±57 875	331 000 ±339 014	136 818 ±159 347	156 000 ±184 031	376 792 ±219 883	596 770 ±348 223	55 375 ±40 294	63 007 ±24 355	189 175 ±234 787	789 717 ±588 080
	No	489 286 ±241 360	219 058 ±56 788	195 429 ±274 025	44 500 ±5 701	57 143 ±88 789	64 600 ±64 640	709 828 ±973 992	126 900 ±46 686	0	0	472 571 ±994 656	16 942 ±83 799
Yemssoa	Yes	520 047 ±209 620	436 697 ±142 653	162 470 ±218 784	90 050 ±114 171	161 882 ±242 270	186 200 ±307 966	463 941 ±314 773	616 693 ±428 190	36 530 ±23 825	64 093 ±75 825	304 777 ±524 718	520 337 ±585 151
	No	588 436 ±189 134	292 167 ±167 592	125 455 ±268 937	252 833 ±139 679	90 909 ±89 717	54 167 ±74 928	671 818 ±518 359	227 833 ±156 756	0	0	299 746 ±553 287	242 667 ±211 698
Soa	Yes	494 957 ±297 850	592 188 ±377 008	250 000 ±533 854	156 250 ±212 867	135 714 ±98 802	25 000 ±53 452	363 571 ±235 190	199 062 ±189 237	44 286 ±36 677	1089950 ±583 578	298 614 ±257 411	878 075 ±413 311
	No	521 071 ±281 414	545 300 ±195 856	527 500 ±903 891	571 539 ±811 036	135 071 ±264 225	172 692 ±337 618	644 321 ±540 890	550000 ±447 009	0	0	785 821 ±802 473	748 931 ±609 968
Mbankomo	Yes	1 118 750***** ±1 000 540	700 225 ±319 061	179 400 ±146 902	165 000 ±124 766	50 000 ±100 000	50 000 ±100 000	803 250 ±1 156 473	610 000 ±829 498	57 500 ±51 726	440 125 ±141 598	-28 600 ±295 018	564 900 ±769 431
	No	564 819 ±252 986	536 918 ±336 455	366 063 ±438 806	323 529 ±347 364	66 875 ±147 726	76 471 ±120 049	406 750 ±204 149	453 411 ±240 279	0	0	274 869 ±385 557	316 494 ±323 817

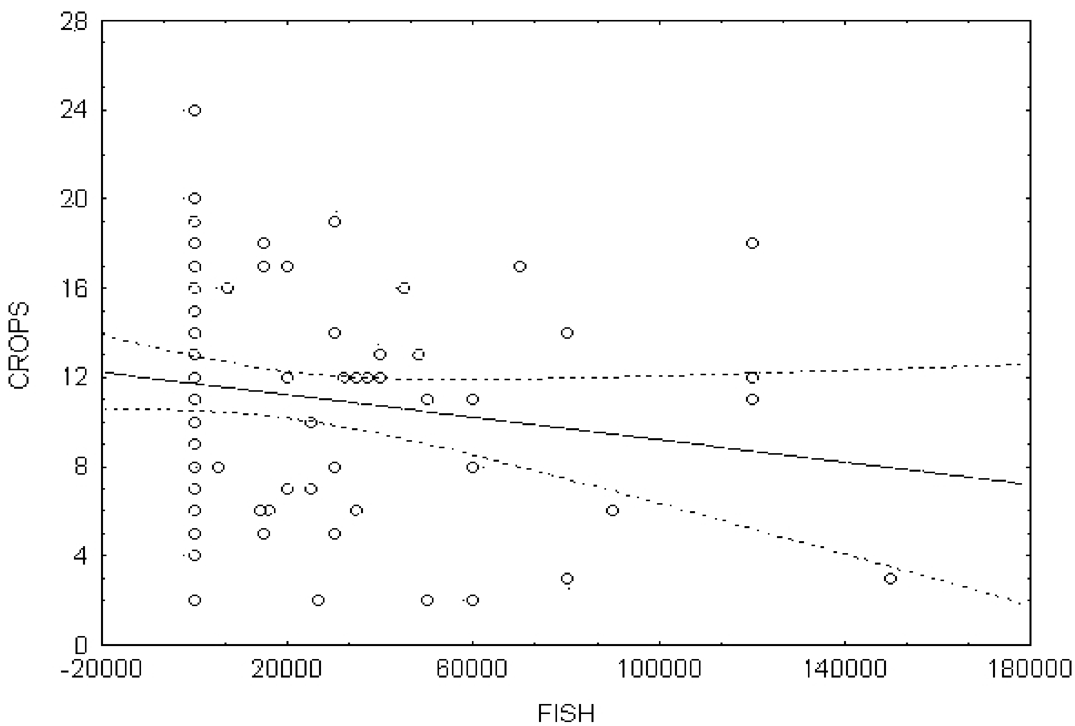
Domain	**IAA?**	**Total Farm Operations**		**Off-Farm Income**		**Non-Ag Income**		**Ag Income**		**Fish Income**		**Net**	
		2000	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**
High Access	Yes	721 791 ±672 756	628 200 ±347 912	224 327 ±422 779	159 167 ±181 932	104 546 ±103 573	33 333 ±68 534	523 455 ±695 431	336 042 ±501 379	49 092 ±40 673	873 342 ±569 701	179 627 ±305 157	773 683 ±542 167
	No	544 403 ±262 865	540 550 ±279 906	441 400 ±687 426	431 000 ±595 300	98 700 ±209 240	118 166 ±239 729	517 617 ±408 946	495 267 ±341 915	0	0	513 313 ±657 862	503 883 ±509 226
Low Access	Yes	487 886 ±206 134	396 879 ±122 873	125 827 ±175 038	210 525 ±277 900	152 036 ±210 574	171 100 ±250 876	427 879 ±278 425	606 731 ±385 356	44 328 ±32 426	63 550 ±55 590	256 941 ±439 686	655 027 ±594 897
	No	532 912 ±221 320	258 935 ±129 580	164 640 ±268 425	158 136 ±146 987	72 000 ±88 976	58 909 ±67 142	692 800 ±791 312	181 954 ±126 240	0	0	396 528 ±819 214	140 064 ±197 769
High Population	Yes	512 729 ±232 047	481 123 ±237 249	188 000 ±330 602	108 964 ±147 811	154 250 ±208 627	140 143 ±270 151	434 667 ±292 452	497 370 ±418 952	38 792 ±27 546	357 195 ±561 308	302 979 ±471 373	622 548 ±558 858
	No	550 712 ±242 830	465 363 ±219 064	350 600 ±717 060	470 895 ±683 451	115 640 ±204 134	135 263 ±284 173	656 420 ±520 213	448 263 ±404 609	0	0	571 948 ±732 809	589 058 ±564 752
Low Population	Yes	611 431 ±566 869	412 254 ±190 729	100 288 ±94 856	303 333 ±317 753	113 667 ±147 847	138 333 ±175 813	483 406 ±582 507	598 975 ±435 826	55 906 ±41 553	125 860 ±154 002	134 731 ±259 456	752 247 ±608 472
	No	529 570 ±246 349	464 676 ±324 734	286 433 ±375 170	260 113 ±325 981	62 333 ±121 845	73 772 ±108 638	547 993 ±685 846	379 205 ±253 016	0	0	367 130 ±728 321	248 414 ±312 631

The overall functioning of rural farms was not significantly affected by the introduction or growth of aquaculture so far engendered, with increased profitability over the project periods being mostly due to increases in cacao (the principal cash crop in the province) prices. In addition, rural farmers in low population density areas (e.g., Akono) were generally less interested in working with an improved marketing strategy, in favour of managing their pond harvests around local needs, such as wedding, funerals and feasts. This could well change over time as the expansion of the collective marketing structure creates positive feedback mechanisms to generate increases in production (through the purchase of higher quality inputs such as manures and/or prepared diets) and sales.

On the other hand, profits in high market access areas were significantly related to the adoption of improved aquaculture. Overall net profits rose from cfa180,000 to cfa770,000 with increases in fish pond income from cfa49,000 up to cfa870,000 over the project period (Figure 4).

These increases were, however, not significantly correlated with crop diversity, which tended somewhat downward with increasing fish yields and net profits. In addition to seeking to lower risk by diversifying their cropping systems (as described above), rural farmers are more or less restricted to the use of on-farm organic resources as fishpond fertilizers. In periurban sites, these on-farm resources were replaced by a smaller number of more effective (i.e., rich in available nutrients) off-farm agricultural by-products, especially purchased dried chicken manure, brewery wastes and brans).

Figure 4. Scatterplot of crop diversity against profits earned by fish farming.



Although not directly receiving support from the project, a few medium-scale periurban farms were initiated during the project period and we compared these with smallholders to determine what might be the potential if capital were not a constraint on investment (as it is for most smallholders). Profitability varied considerably among these farms (Table 5). Of five systems subjected to detailed analysis, two lose money each year. Net returns to management on profitable farms ranged from a low of cfa 0.3 million, to a high of cfa 3.87 million (overall weighted average = cfa 0.99 million). Payback period for the initial investment on farms turning a profit ranges from five to 28 years. Only two farms can be considered solid investments. Nevertheless, the potential of aquaculture systems to be productive and profitable is apparent from the data collected. It is estimated that the five surveyed farms could increase their production from the current 7.6 to at least 44 tons of fish per annum, returning average profits of cfa 21.5 million, if basic principles of fish culture were adopted.

Table 5. Costs and returns per hectare of periurban aquaculture in Yaoundé, Cameroon for a subset of five farms in cfa (1 USD = 550 cfa). Averages were weighted on the basis of total pond area on each farm.

Item	Farm Number 1	2	3	4	5	Weighted Average
Fixed costs (depreciated)						
Pond construction	468,000	1,106,667	522,667	146,667	672,000	494,024
Tools and equipment	82,790	410,023	120,261	265,288	55,052	121,178
Land rent	25,000	25,000	25,000	25,000	25,000	25,000
Subtotal fixed cost	575,790	1,541,690	667,928	436,955	752,052	640,202
Variable costs						
Fingerlings						
Tilapia	216,540	105,920	292,280	277,780	387,280	235,918
Clarias	20,550	314,200	353,500	4,875	24,500	59,698
Heterotis	32,700	29,400	192,000	22,750	0	39,711
Other	450	50,100	0	2,250	907,800	80,310
Subtotal fingerlings	270,240	499,620	837,780	307,655	1,319,580	415,636
Feed & Fertilization						
Pig manure	228,000	222,000	0	0	0	169,246
Chicken manure	8,187	399,728	0	0	0	29,349
Brewery waste	10,500	0	10,000	0	0	7,877
Composed feeds	0	0	751,471	365,321	742,882	152,157
Subtotal Feed	246,687	575,790	1,541,690	667,928	436,955	752,052
Labor	154,890	1,478,463	1,568,627	802,903	486,563	425,572
Subtotal Variable Cost	580,020	3,456,546	3,975,034	1,913,461	2,292,706	1,266,780
Total costs	1,155,810	4,998,236	4,642,962	2,350,416	3,044,758	1,906,982
Costs per kg of production	772	999	1,103	2,877	2,851	1,115
Revenues						
Fingerlings						
Tilapia	79,080	0	0	0	0	54,128
Kanga (*Heterotis nilotcus*)	17,850	0	0	0	0	12,218
Catfish	0	2,610,000	0	0	0	588,620
Subtotal fingerlings	96,930	2,610,000	0	0	0	654,966
Table fish						
Tilapia	427,000	234,677	2,454,058	443,075	607,000	572,339
Kanga	345,313	2,426,326	1,547,908	227,000	0	510,582
Catfish	1,117,720	3,021,938	761,881	206,000	117,000	1,028,152
Snakehead	35,185	205,051	173,475	92,491	0	57,718
Carp	0	0	0	0	567,688	48,023
Vundu (*Heterobranchus sp*)	0	369,431	0	0	0	21,945
Subtotal table fish	1,925,218	6,257,423	4,937,322	968,566	1,291,688	2,238,759
Subtotal Revenues	2,022,148	8,867,423	4,937,322	968,566	1,291,688	2,893,725
Net returns to management	866,338	3,869,187	294,360	-1,381,850	-1,753,070	986,743
Profits to earnings ratio	0.43	0.44	0.06	-1.43	-1.36	0.34

Contrary to published reports (which seem to include women who contribute marginally to pond labour), women's direct involvement in aquaculture is currently low in the project zone. Only 11 of the 100 targeted farmers (out of 23 women who came to the village meetings) are female and only 2 (albeit two of the most productive) of the farmers active at the end of the project were female. To understand this, an in-depth analysis of women's workload and daily time allocation was conducted in collaboration with CIRAD and ISTOM. Findings indicate that the daily and weekly program of regular activities disallows the dedication of large blocks of time to any single enterprise. Such income generating activities as can be undertaken in evenings or in spare moments are much more popular. Women expressed interest in working in groups (3 of the original 11 women involved in the project were actually representatives of groups) so that tasks can be distributed among several women, making them easier to fit into the existing routine. Overall, 19 women's groups with 223 members are active in the four target villages.

In addition, the survey discovered that the often reported heavy workloads imposed on women by traditional African society are not distributed evenly, with girls and young women between the ages of 8 and 25 bearing the bulk. Women who already have female children old enough to chop firewood, carry water and tend babies spend much more time on income generating and social activities. For such women, locating aquaculture facilities (e.g., backyard tanks) might make aquaculture easier to manage, but this idea never generated very much interest among participating female farmers.

Likewise, efforts to encourage village women to take an active role in urban marketing as they often do in capture fisheries, was met with considerable scepticism. Women regularly cited the large number of road blocks (at each of which, anyone carrying produce is subjected to "informal taxation"), their fear of reprisals from existing fish traders and the danger of carrying relatively large amounts of cash in refusing to get involved.

On the other hand, improved fish production and marketing made substantial contributions to the 22 women who currently dominate live fish retailing in Yaoundé. Our early market survey data estimated that these women sell a total of about 500 kg of fish per day at an average retail price of cfa 2500 per kg. Prior to the intervention of the collective marketing scheme tested in the final year of the project, none of the fish sold by local fish farmers were handled by this "formal" marketing mechanism, being sold on the pond bank directly to consumers. The collective marketing experiment sold these women 400 kg of fish for resale and if the scheme can be extended to include all existing fish farmers, the potential additional revenues to female fish mongers is on the order of cfa 9 million per annum.

In the absence of state-sponsored social security, rural societies in southern Cameroon provide social safety through various institutions and norms of behaviour. Reciprocal gift giving is often a component of the social safety net that is commonly practiced among fish producers in rural areas and the possibility that this institution might be attenuated with increasing commercialisation of aquaculture is a concern. However, evidence suggests that the quantity of harvested fish distributed free among friends and family relations is similar among periurban (54%) and rural producers (41%). Periurban farmers attributed the slightly higher amounts kept for the family to the availability of freezer space in electrified areas, which allows for the preservation of fish for later consumption.

In general, increases in social capital resulting from the growth of IAA in project areas were not noticeable. At the end of the project, farmers listed "conflict with neighbours" as one of the top three constraints to expansion, after fingerling supply and market access. The original four fish farmer groups with whom we worked disintegrated due to personal feuds among members, exacerbated by the different levels of interest and commitment among the original membership. Some of these farmers ended up working alone, with others going off to form their own groups. Incentives for group action were clearly lacking.

Mbankomo, the low population density, high market access site, was particularly fractious. Strong group leadership, which unfortunately had a dictatorial and coercive flavour, created strong disincentives to collaborate. Information delivered to the group remained with only a few members, increasing strife and tension, and kept Mbankomo in the lower range of productivity throughout the project. Being considered a high potential area for commercial farming due to its proximity to town, this area also had a long history of development projects. Some of these had used financial incentives to encourage participation in group activities and when these were not forthcoming from the aquaculture project, complaints arose and accusations of graft were levied against the group leadership (on the assumption that money had been given by the project, but it had been diverted by those in charge). Towards the end of the project, the group leader's vehicle was burned.

In response to these difficulties, NGOs were recruited to assist in managing group dynamics. Small-scale, revolving credit and marketing schemes were put in place in order to give the groups a reason for being (other than sharing technical advice) and these seemed to have a positive effect among members, but relations between fish farmers and the larger community worsened as aquaculturists refused to sell their fish at locally discounted prices. Thievery and sabotage increased as jealousy over income generated by aquaculture on what had previously been considered low-value, but communal land resources (i.e., swamps) increased.

For aquaculture (or any other enterprise) to succeed in bringing economic prosperity to isolated rural communities, such social levelling mechanisms must be taken into consideration. In the short term, the wider community benefits little or not at all from increases in fish production that are exported to urban markets. Cash-poor villagers cannot pay the higher prices demanded by farmers who now have an option to sell elsewhere. If these problems can be ignored or dealt with in the shorter term, continuing to provide support to very small-scale farmers, may, in the longer term, succeed in capitalizing and intensifying these small ventures, creating employment opportunities, lowering the cost of fish and extending the benefits of aquaculture to the larger community.

If community conflict continues, however, alternative approaches will be needed. A shorter capitalization period might, for example, be achieved through targeting somewhat better-off farmers who are capable (in terms of resources and education) of profitably investing in aquaculture in the short term. Alternatively, a broad program of support to market-oriented agriculture in general could enable non-aquaculture farmers to also link to urban markets, thus increasing their fish-purchasing power and taking pressure off of fish farmers who are currently perceived as benefiting unfairly from exploitation of communal resources and generally not living up to the expectations of poorer neighbours.

4. Aquaculture Sustainability can be Improved Through the use of Indigenous Species: To add value to rainforest river biodiversity through aquaculture of indigenous species, the diversity and diets of commercially important fishes of the Nyong River were examined over the course of two years. Monthly catch sampling from commercial fishers found that, out of 75 species previously reported for the upper and middle Nyong (plus 9 new species added in this study), only 36 are regularly captured, and only 17 of these are sufficiently abundant and large enough to be of commercial importance as food fish (Table 6).

The two most important of these are the alien *Oreochromis niloticus* and *Heterotis niloticus*. Although quantitative data on the ecosystem prior to the introduction of these species is lacking, there is circumstantial evidence that indigenous species may have suffered from competition with introduced alien species and/or changes in the ecosystem resulting from poor land use management. Of particular concern are species which undertake reproductive migrations at times of lowest water quality. Of the commercially important species, most species target detritus and aquatic insects. Compared to the foods available in small fishponds, only the alien *O. niloticus* and *H. niloticus* appear well-suited to the conditions prevailing in Cameroonian aquaculture.

Table 6. Fish species captured by the commercial fishery of the Nyong River. Fish indicated with + are important in the commercial catch (CC), while those with – are non-targeted by-catch.

Family	***Species***	**CC**	**Family**	***Species***	**CC**
Alestiidae	*Brycinus longipinnis* *Brycinus macrolepidotus*	- +		*Barbus bynni* *Barbus holotaenia*	- -
	Brycinus opisthotaenia	+		*Labeo cf lukulae*	+
Anabantidae	*Ctenopoma maculatum*	-		*Opsaridium ubangense*	-
Channidae	*Parachanna obscura*	-		*Raiamas batesii.*	+
Cichlidae	*Hemichromis elongatus*	+		*Varicorhinus spp*	-
	Oreochromis niloticus	+	Eleotridae	*Eleotris spp.*	+
	Sarotherodon mvogoi	-	Hepsetidae	*Hepsetus odoe*	+
	Tilapia sp.	-	Mochokidae	*Microsynodontis batesii*	-
Clariidae	*Clarias camerunensis*	-		*Synodontis batesii*	-
	Clarias jaensis	+		*Synodontis steindachneri*	-
Claroteidae	*Chrysichthys cf. auratus*	-		*Synodontis spp.*	-
	Chrysichthys cf. nigrodigitatus	+	Mormyridae	*Brienomyrus brachyistius*	+
	Parauchenoglanis balayi	+		*Marcusenius moori*	+
	Parauchenoglanis guttatus	-		Mormyrus tapirus	+
	Parauchenoglanis longiceps	+		*Petrocephalus simus*	+
Cyprinidae	*Barbus aspilus*	-	Osteoglossidae	*Heterotis niloticus*	+
	Barbus brazzai	-	Schilbeidae	*Schilbe multitaeniatus*	+

Although options for foodfish production from indigenous species seems low, a number of species were identified with substantial potential as ornamental fishes. Among those identified in first and second order streams in SW Cameroon, the genera of greatest interest to the ornamental fish trade include: *Aphyosemion, Benitochromis, Brienomyrus, Brycinnus, Caecomastecembelus, Chiloglanis, Doumea, Parauchenoglanis, Pelvicachromis* and *Procatopus*. Retail value of these fishes range from $2.00 to $20.00 in Europe. Partial enterprise budgeting for a delivery of 8.5 kg of ornamentals (the minimum amount to obtain discounted air freight) sold wholesale at $1.00 per fish shows a substantial potential for profitability (Table 7).

However, the total value of the fish species existing in the wild at any of the sites sampled is insufficient to support any significant expansion of the exploitation rate. Most of these species have very low fecundity and cannot be expected to rapidly repopulate heavily exploited streams. However, aquaculture of these fishes could offer substantial livelihoods options, and create added incentives to sustainably management forest ecosystems. Based on project findings, a World Bank funded project is now testing the feasibility of community-based, commercial aquaculture of rainforest fishes.

Table 7. Partial enterprise budget for ornamental fish export from Cameroon to Germany.	
Costs	
Shipping per 208.5 kg (100 l water + fish + containers ~ 5 boxes) @ $3.00/kg	$ 600
Veterinary fees in Germany	$ 30
Local transport (300 km x $0.16/km)	$ 48
Fish feeds	$ 22
Maintenance	$ 100
Payment to fishers ($0.25 per fish)	$ 425
Government Tax	?
Total	$1,225
Revenues	
Wholesale of 1700 fish (@ 5 g x $1.00 per fish)	$1,700
Profit per five boxes shipped	$ 475

Sponsored Research

In addition to the main themes, a number of ancillary research projects dealt with a range of constraints faced by Cameroonian farmers, as identified in a series of participatory village meetings, interviews with local specialists and government consultations. The most important of these are associated with feeding and fingerling supply, and hence received most of our attention.

Alternative Feeding Strategies: A range of agricultural by-products were tested either as pond fertilizers (through the use of compost) or in the form of prepared and pelleted diets. Materials compared included common weeds (*Tithonia diversifolia, Chromolaena odorata*), avocados, cocoa husks, brewery waste, chicken manure, pig manure and coffee hulls. Several of these materials were demonstrated to be economically viable and labour saving alternatives to the typical compost fed with household wastes and green manures (Table 8). Based on these findings, a training and extension program was put in place to expose as many farmers as possible to the benefits of improved feeding technology.

Table 8. Locally available agricultural by-products used in prepared fish diets.

Material	Price per Kg ($1.00 = cfa 550)	Food Conversion Ratio	Specific Growth Rate	Feed cost/kg fish
Cocao Husks	284	1.28	2.16	364
Brewery Waste	282	0.77	2.31	217
Avocados	167	2.49	0.44	415
Chromolaena	152	2.27	2.51	381
Chicken Manure	308	0.48	2.52	148
Coffee Hulls	297	1.08	2.28	321

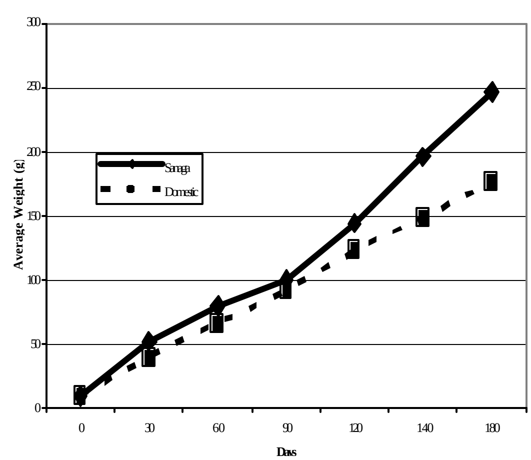
Hatchery Management: To target development efforts, the technological options for investments in *Clarias gariepinus* hatchery systems were compared for cost, average weight, survival and profitability in the context of periurban Yaoundé (Tabale 9). Costs were proportional to the level of intensity of production, with labor accounting for about 70% of total costs. The highest input/highest stocking density treatment was the most profitable, but only returned fcfa 90 per m^2. All other systems either lost money, or returned minimal profits. The critical factors in profitability were found to be survival and final average weight, indicating the need to intensify the low production technology currently employed.

Table 9. Fingerling survival, final average weight, number harvested and profitability data per m^2 for *Clarias gariepinus* nursing systems of increasing technical intensity tested in triplicate (over 35 days) in periurban Yaoundé, Cameroon. Price of fingerlings is dependant upon size of fingerlings: >5 g = cfa 100, 2-5 g = cfa 75, < 2 g = cfa 50 (1 USD = cfa 500).

System	Survival (%)	Final Average Weight (g)	Number Harvested per m^2	Gross Revenue per m^2	Net Profit per m^2
1	48.5 ± 26.31	5.9 ± 2.23	3.6 ± 1.97	322.0 ± 163.23	15.8 ± 183.71
2	26.1 ± 14.67	1.9 ± 1.08	3.9 ± 2.20	214.1 ± 92.01	-134.7 ± 111.52
3	46.8 ± 43.35	5.5 ± 3.23	7.0 ± 6.50	527.4 ± 485.67	4.13 ± 488.83
4	28.4 ± 6.12	4.2 + 0.31	8.5 ± 1.84	723.75 ± 268.33	-126.6 ± 275.87
5	64.9 ± 3.42	3.9 ± 0.76	19.5 ± 1.02	1459.5 ± 76.84	91.0 ± 76.84

Wild (Sanaga River) and captive populations of *Oreochromis niloticus* were compared on-farm and on-station in the Central Province of Cameroon to determine the degree to which genetic deterioration of stocks may have occurred during domestication and breeding (Figure 8). On-station, average weight at harvest was 284.3 ± 16.2 g and 178.1 ± 9.9 g for Sanaga and domesticated populations, respectively. On-station specific growth rate was 0.0660 ± 0.0022 g/day and 0.0555 ± 0.0016 g/day for Sanaga and domesticated populations, respectively. On-station standing stock at harvest was 5747.3 ± 624.4 kg/ha and 4170.3 ± 233.4 kg/ha for Sanaga and domesticated populations, respectively. Differences in average weight at harvest and specific growth rate on-station are significant at P < 0.003. Differences in standing stock at harvest on-station are significant at P < 0.015. On-farm, average weight at harvest was 121.1 ± 26.5 g and 87.5 ± 17.2 g for Sanaga and domesticated populations, respectively. On-farm specific growth rate was 0.0442 ± 0.0057 g/day and 0.0358 ± 0.0047 g/day for Sanaga and domesticated populations, respectively. On-farm standing stock at harvest was 2454.2 ± 445.6 kg/ha and 1667.8 ± 352.2 kg/ha for Sanaga and domesticated populations, respectively. The Sanaga River population consistently out-performed the captive population. Final individual weight of captive fish averaged 39% less than wild fish on-station and 42% less than wild fish on-farm.

Figure 5. Comparison of growth in wild and captive O. niloticus populations in Central Province.



CONTRIBUTION OF OUTPUTS

The technologies developed and transferred through participatory research and have underpinned the increases in pond productivity cited above. By connecting rural farmers to markets, the process of capitalization and intensification has begun. The various ancillary research projects, most of which were also conducted in a participatory mode, have created practical options for intensification that are now being realized through the efforts of local

NGOs. There is now considerable interest in aquaculture at all levels. Rural farmers are building more ponds and new farmers taking up aquaculture. Middle-income farmers are intensifying their production systems and/or investing in hatchery technology.

In addition to these farm-level contributions, a key element of the project's modus operandi has been to work with other agencies concerned with aquaculture development. In Cameroon, the RET approach has created a new, and much more productive, relationship between MINEPIA (extension) and IRAD (research). Prior to the creation of the RET, the relationship was very much top-down with IRAD providing only occasional training to MINEPIA extension agents, donor-funded projects permitting. Based on the collective experiences had through the course of collaborative fieldwork, the relationship is not only more productive, but friendlier, and is no longer one of teacher and student. The greater knowledge of science and agriculture possessed by IRAD is now linked directly to both extension and farmers through a mutually understood, and mutually beneficial, mechanism.

In addition to national partners, the project has contributed extensively to FAO's regional efforts to reform the sector. The lessons learned through our work in Central Province, Cameroon have been fed into two main initiatives, one at national and one at the regional level:

The Strategic Framework for Aquaculture in Cameroon. This planning document developed jointly by FAO, WorldFish, MINEPIA and IRAD puts in place a structure and set of guidelines for improving government's involvement in encouraging aquaculture development. This document spells out the roles of government, NGOs and the private sector in the provision of basic support services and policy, and will serve as the template for further policy development in Cameroon. The intent of the Strategic Framework is to take advantage of existing, pro-development government policies to describe a practical and feasible approach to implementation. Having been adopted by the MINEPIA, the Strategic Framework is now being implemented, the first step being an FAO-financed review of relevant legislation that will need to be modified so as to concentrate on high-potential areas for aquaculture, privatize government aquaculture stations and create additional RETs. The full text is appended.

The Limbe Declaration on Smallscale Aquaculture , a consensus statement by delegates to the FAO/WorldFish Workshop on Small-scale Aquaculture, 23-26 March 2004, Limbe, Cameroon. The Limbe Declaration was designed as a policy tool to regionalize the Strategic Framework. The full text follows:

The Limbe Declaration

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 project 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.

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 approp0riate 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.

In addition, the project made substantial contributions in the form of datasets, action research activities (some of which are on-going through the end of 2005) and input to seminars to the NARO-MAAIF Fish Farming Project sponsored by DFID in Uganda, the University of Stirling-WorldFish Periurban Aquaculture Project, the IITA Alternatives to Slash and Burn programme and the CIAT Integrated Agricultural Research for Development (IAR4D) initiatve

These, and a large number of formal and informal interactions with the Government of Cameroon, IITA, external reviewers, Board of Trustee members, CIRAD, IRD, FAO, World Bank, IMF, *inter alia*, have widely disseminated our findings and contributed to the development of better policies at a number of levels. This process will continue, in fact, increase, as final data analysis has revealed important lessons (summarized in this report) that will be of interest to government, donor agencies, NGOs and farmers in Africa.

WorldFish and its partners in Cameroon are carrying forward the outcomes of the Development of Integrated Aquaculture-Agriculture Systems for Small-scale Farmers in the Forest Margins of Cameroon project. Through a series of consultations between farmers and local government, new local and regional projects are being developed. To provide support to small-scale hatcheries in an effort to improve both their productivity and the quality of the fingerlings they produce, a regional participatory research project is being designed The findings of the market access research are feeding directly into new local initiatives to sell local aquaculture products for a profit. Based on the findings of the river biodiversity surveys, a business plan is being developed for the sale of ornamental fishes. All of these new activities are being implemented in a participatory mode in close collaboration with local NGOs, farmers groups, fish wholesalers and retailers and the Government of Cameroon.

ANNEX A

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Other Dissemination Mechanisms

Technical Bulletins:

1. Elever le tilapia en association avec un prédateur.
2. L'importance d'une compostière.
3. Constructions des étangs en milieu rural.
4. L'entretien d'un étang.
5. L'alimentation du poisson.
6. La protection des larves de Clarias en étang piscicoles.
7. Transport et mise en charge des alevins.
8. Nutrition des poissons a base des granules piscicoles.
9. Fabrication d'un séchoir a base des matériaux locaux pour les granulés piscicoles
10. Alimentation des poissons d'aquarium
11. Les poissons d'aquarium du Cameroun

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- Brummett, R.E. 2003. Rainforest river biodiversity. IITA/IRAD Seminar Series, 18 November.
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Dataset Management

All data has been persevered in electronic and hard copy and deposited at the IITA Humid Forest Ecoregional Center Library, an integral part of the IITA data and documentation management system. Copies of articles and presentations are available from WorldFish Center HQ, Penang, Malaysia. Electronic copies of RESTORE are available upon request.