ADiM Working Paper 5

Evaluation of Two Farmer's Approaches for Aquaculture Development in Malawi

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Contents

1. Background

The biggest challenge Malawi has for the aquaculture development is its limited resources. The Government, though it tries hard, the issue of lacking resources will not be solved in a day. Considering such situation, farmers should not just wait and depend on the Government to provide the way for the development, but they themselves need to seek and move forward to the development partnering with fellow farmers, NGOs and the Government.

The Pilot Project focuses on two approaches, 'Innovative Farmers Approach' and 'Farmer's Club Approach'. The Pilot Project was implemented from December, 2003 to February, 2005. Through the implementation, its effectiveness and feasibility for the aquaculture development are verified.

This Working Paper explains each approach in Chapter 2 and 3 respectively. Approaches are verified based on the assumptions set forth at the beginning of the Project. Chapter 4 discusses the possibility of application of two approaches into the National Aquaculture Strategic Plan (NASP).

2. Pilot project Component 1 "Innovative Farmers Approach"

2.1 Objective

'What is innovative farmers approach?'

The objective of the 'Innovative Farmers Approach' was to verify the effective technology development and extension on commercial aquaculture system through capacity building of so-called 'innovative' farmers. Through frequent communication among farmers, and between farmers and the Department of Fisheries (DoF) by networking, the Pilot Project aimed to maximise their capacities on technology development and identify their role in 'farmer to farmer' extension.

2.2 Assumptions for the Verification

Three assumptions were set up in order to verify innovative farmers' potentials as entrepreneurs who apply new technologies and act as key persons in 'farmer to farmer' technology transfer. The assumptions are:

- Innovative farmers quickly adopt new ideas, therefore they are more productive,
- Innovative farmer's network leads information and technology transfer among the farmers, and
- Innovative farmers have an influence on their communities, therefore they promote aquaculture extension.

2.3 How to Verify the Assumptions

In order to verify the above assumptions, the following activities are implemented during the Pilot Project.

1. Identification of innovative farmers
2. Creation of farmers' network
3. Baseline survey
4. Training and visit (needs assessment, national training course, study tour, farmer-to-farmer visits)
5. Farmers' small project
6. Evaluation (mid-term evaluation, evaluation survey, and final evaluation)

The time flow of activities is described in Figure 2.1.

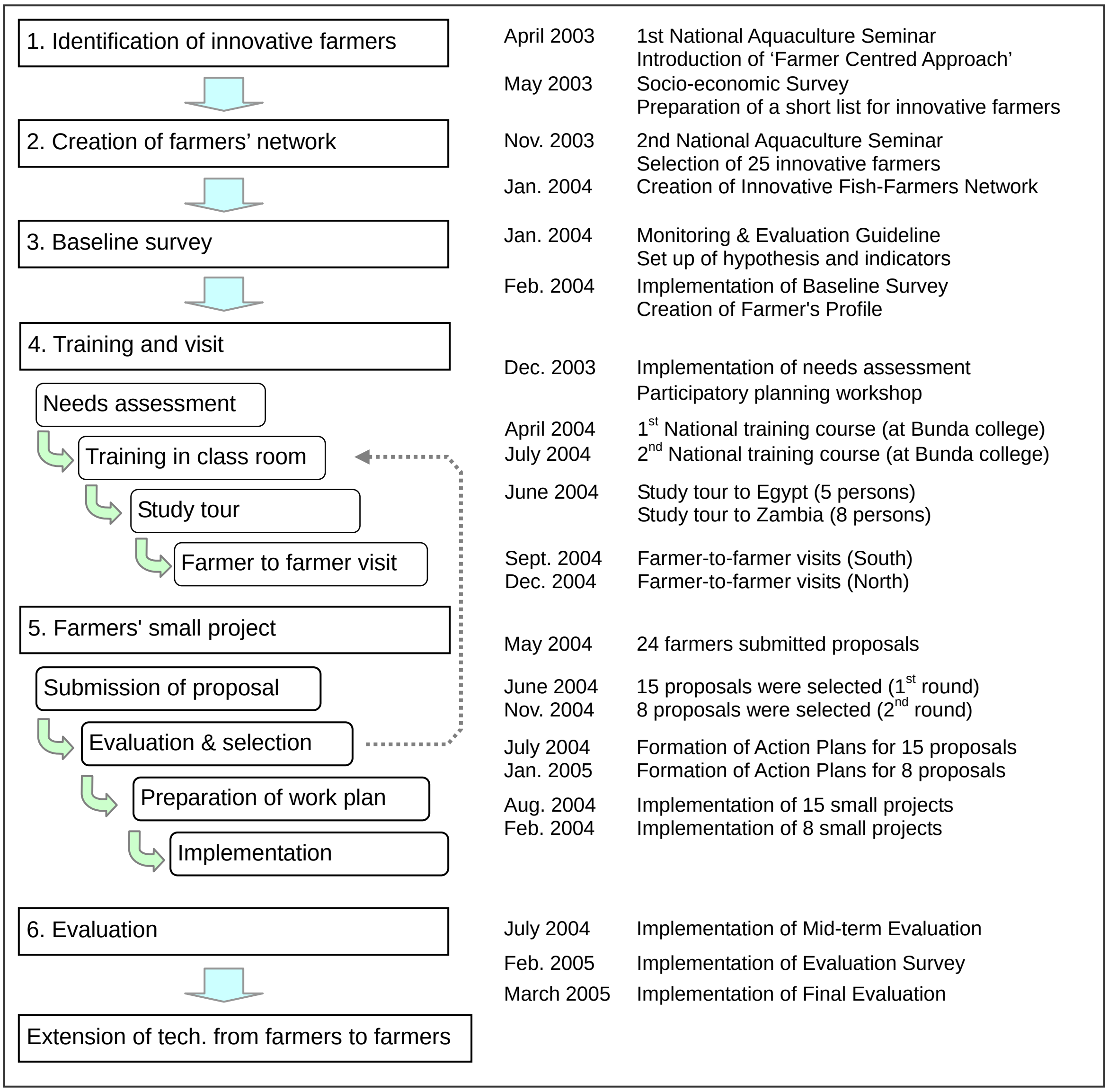


Figure 2.1 Activities of the Pilot Project Component 1 and Achievement

1. Identification of innovative farmers

Prior to the 2nd National Aquaculture Seminar, 25 innovative farmers were identified as 'innovative farmers' by the ADiM Study team and DoF for the Pilot Project. They are selected from all over the nation. Their names and locations are shown in Attachment 2 and Attachment 3. Their selection criteria were listed in Attachment 4.

2. Creation of farmers' network

In January 2004, all 25 selected members gathered in Lilongwe and agreed to create a farmers' network, so-called 'Innovative Fish Farmers Network Trust (IFFNT)'. They discussed with DoF on their registration to the Government as a legal entity. They have elected 10 committee members (Attachment 5).

3. Baseline survey

In February 2004, the baseline survey was implemented for all 25 farmers. The baseline survey aimed to understand their technical abilities and socio-economic status.

4. Training and visit (needs assessment, national training course, study tour, farmer-to-farmer visits)

After the needs assessment, two national training courses, study tours to Zambia, Egypt, and Japan, and two farmer-to-farmer visits were implemented. Those technical training activities were sub-contracted to Bunda College of Agriculture, the only College in Malawi which has Aquaculture and Fisheries Science Department. Farmers whom participated in each activity are listed in Attachment 6.

5. Farmers' small project

Based on what has been taught, 15 farmers have applied and been accepted their proposals for the small projects for Phase I and 8 farmers for Phase II. Farmers have developed action plans together with the ADiM Study team members, and initiated their small projects. The outline of the small project implemented by each farmer is listed in Attachment 7.

6. Evaluation (mid-term evaluation, evaluation survey, and final evaluation)

The mid-term evaluation workshop was implemented in July 2004 and the results were compiled in the report called 'Master Plan Study on Aquaculture Development in Malawi: Field Report The Pilot Project -Mid-term Evaluation-' (2004). In February 2005, the evaluation survey (technical survey and socio-economic questionnaire) was carried out and the participatory evaluation workshop was held in Lilongwe. During the period of the Pilot Project, continuous monitoring was carried out by both the ADiM Study team and Bunda College of Agriculture. Lastly, follow-up surveys and interviews were carried out in order to obtain additional information.

The budget allocated for above mentioned activities was US$ 49,000 (Attachment 8).

2.4 Results

Three assumptions were verified through various activities implemented during the Pilot Project. The specific indicators used for the verification were listed in the Table 2.1.

Table 2.1 Assumptions, methods for verification, and indicators

Assumptions	Methods for Verification	Indicators
Innovative farmers quickly adopt new ideas, therefore they are more productive	Evaluation Survey Participatory evaluation workshop	1. Introduction of new technologies through trainings 2. Record keeping of fish farming activities 3. Drop out rate from the network 4. Changes in fish farming among members
Innovative farmer's network leads information and technology transfer among the farmers	Participatory evaluation workshop Monitoring	1. Amount of information exchanged among farmers 2. Cost spent for transportation and communication
Innovative farmers have an influence on their communities, therefore they promote aquaculture extension	Socio-economic questionnaire for the evaluation survey Follow-up interviews with selected farmers	1. Number of visitors innovative farmers has received 2. <u>Perceptions of farmers towards an innovative farmer who live vicinity to their community</u>

Source: Author (2005)

2.4.1 Innovative farmers quickly adopt new ideas, therefore they are more productive

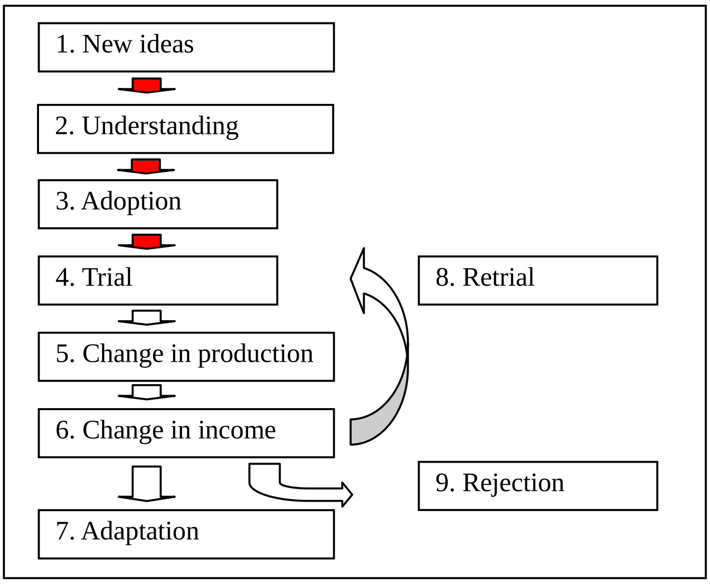
<u>Why has this assumption been chosen?</u>

80% of Malawian population consists of farmers. Under this assumption, the high adoptability of information and technologies of selected innovative farmers and their potentiality of being a model farmer are verified.

(1) New ideas will be (2) understood, (3) adopted and then, (4) tested. After its trial, if there is any positive change in (5) production or (6) income, the idea will be (7) adapted. If there is not positive change in production or income, the idea is (8) retried with different condition, or otherwise, (9) rejected. The flow of information is shown in Figure 2.2. However, majority of farmers in Malawi neither have much opportunity to be exposed to new ideas, nor have ability to understand. Even if they manage to understand and adopt new ideas, they cannot go for the trial because they cannot bear the risk.

The presence of farmers who can adopt and try new ideas opens the possibility of development among Malawian farmers through providing a model.

It is difficult to observe an increase in both income and production within the period of the Pilot Project. Often those changes will be seen at least after one or two agricultural cycles. Therefore, this assumption is verified through looking at their capacity on adoptability of new ideas.



Source: Author (2005)

Figure 2.2 Flow of Information

<u>How has it been verified?</u>

Information and ideas are provided to farmers through a series of trainings. Those information and ideas are listed in Table 2.2. The verification was carried out through the evaluation survey and participatory evaluation workshop.

Table 2.2 A Series of Trainings and Information and Ideas Provided

Trainings	Information and Ideas provided
Needs assessment	Site tours for Dr. Chinkhuntha's farm (Integrated agriculture, water irrigation)
Baseline survey	Record keeping (On-the-Job Training)
1st National Training Course	Basic aquaculture technology (pond management including pond design, draining and drying, water & soil chemistry and fertilization, production management including brood stock management, stocking & harvesting, husbandry, food & feeding, pond construction technology, all male technology, challenges for large-scale commercial aquaculture) Site tours of facilities of Bunda College
2nd National Training Course	Integrated aquaculture technology (Integrated Aquaculture and Farm Design and Layout, Integration of fish farming with livestock including pigs, cattle and poultry, improved feeding technology including usage of soya and pellet) Site tours of facilities of Bunda College
Study Tour	Advanced Aquaculture technology and its policy in Zambia, Egypt and Japan (education system on aquaculture, fresh water aquaculture carp & trout, research & extension at prefecture level, carp cage culture, possibility of aquarium, lake fisheries & resources management, cage culture technology on sea bream & yellow tail, fish feeding technology, fisheries policy at prefecture level, and Japanese fisheries administration system, etc.)
Farmer-to-farmer visit (South)	Innovative ideas from innovative farmers in Southern region (Mr. Nikoloma, Mrs. Mkalialinga, Mr. Binali, Mr. Twaibu, and Mr. Mlemba) and farmers' clubs in Chingale ADP
Farmer-to-farmer visit (North)	Innovative ideas from innovative farmers in Northern region (Mr. Ngambi, Mrs. Chavula, Mr. Msiska, Mr. Mzimba, Mr. Kamanga and Mr. Misyali)

Source: Author (2005)

Following indicators are used for the verification.

Indicator 1: Introduction of new technologies through trainings

Indicator 2: Record keeping of fish farming activities

Indicator 3: Drop out rate from the network

Indicator 4: Changes in fish farming among members

<u>Indicator 1: Introduction of new technologies through trainings</u>

Six farmers newly started applying soya for feeding after participating in a series of trainings. Three farmers invented their own pellet machines and started pellet feeding.

Number of farmers who apply manure and fertiliser in the ponds has also increased. The number of farmers who applied manure has increased from 18 to 24, though the quantity itself has decreased. The number of farmers who applied fertiliser has also increased from 4 to 12. The quantity of fertiliser applied has also increased from the average of 8.58kg/ha to 123.44kg/ha (Table 2.3). Yet, we should note that some farmers were provided fertiliser by the Pilot Project for their small projects.

Table 2.3 Changes in the Number of farmers who applied Manure and Fertiliser in the Pond and its Quantities

	Manure		Fertiliser	
	2004	2005	2004	2005
Number of farmer adopted	18	24	4	12
Quantity used per farmer (kg)	695.00	541.40	2.44	17.16
Ave. quantity used kg/ha (kg)	4,954.36	3,428.57	8.58	123.44

Source: Baseline survey (2004) and evaluation survey (2005)

In the participatory evaluation workshop, farmers have listed technologies those were newly introduced and tried at their own ponds. 11 mentioned about feeding technologies whereas 6 mentioned about fertilising and manuring technology. 4 gave an integrated farming technology as something they have tried at their farm (Table 2.4).

Table 2.4 Technologies and the number of farmers that have adopted the technologies

Technologies newly introduced and adopted by farmers	No. of farmers*
Good feeding practices by developing the good feeding rates and feeding the fish at one point in the pond	8
Proper fertilisation of the ponds	6
Integration of fish farming with livestock to have enough manure for the pond	4
Growing of leafy vegetables and crops to provide enough greens for feeding *Tilapia rendalli*	3
Use of pulses like soya beans and groundnuts cakes for feeding fish	2
Introduction of soya beans for the provision of high quality protein feed for feeding *Oreochromis shiranus, Oreochromis karongae and Clarias gariepinus*.	2
Good practices for the establishment of broodstock populations	2
Fry skimming and stocking them in nursery ponds	2
Intensification on the use of grass material for composting	2
Dyke reinforcement using grass	1

* Multi-answer was welcomed, sample number was 16.
Source: Participatory Evaluation Workshop (2005)

Indicator 2: Record keeping of fish farming activities

One of the indicators for measuring the management ability is a record keeping. 40% of innovative farmers are keeping good records (10 out of 25). However, 40% keeps no records, or if they do, very poorly[1].

Indicator 3: Drop out rate from the network

There have been two members who dropped out from the network[2]. 8% of drop out rate is considered to be low (2 out of 25). In general, innovative farmers are zealous in learning. 20 farmers had over 70% of a participation rate for a series of training (except the study tour) as it is indicated in Attachment 6.

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1 Data were not available from other 20%.
2 Considering those whom had lower than 50% participation rate in trainings provided and did not submit proposals for the small projects (Attachment 5).

Indicator 4: Changes in fish farming among members

There observed various changes in fish farming practices among innovative farmers before and after the implementation of the Pilot Project. It is not a mere technology transfer, however. It is a change in the mindset of farmers towards aquaculture. It is thought that the new concept of 'aquaculture as a business' has caused following changes in their fish farming practices. Yet, those changes are still at the trial stage reflecting their new mindset and they do not always result in immediate production or income increase.

Change in species composition on farms –increase of T. rendalli

There was a clear shift in species preference from *O. shiranus* at baseline to *T. rendalli* at the evaluation survey. This was an important development which indicated that farmers were shifting toward producing fish for sale to commercial markets rather than local sales or household consumption. Farmers believe *T. rendalli* could be sold at a higher price on the national market (though it is not proved by the study done by one of the ADiM Study team member). It was also cheaper to feed and has the potential to integrate well with other farming activities such as vegetable, sweet potato, cassava, etc. and production.

Change in species composition on farms –increase of O. karongae

The importance of *O. karongae* which is a commercially most popular species to the farmers was evident. *O. karongae* were commonly held in monoculture ponds which were generally better fertilized than the ponds of other species. Farmers were feeding high quality, expensive feeds to their *O. karongae*.

Change in species ratio in ponds

The shift toward *T. rendalli* monoculture in ponds indicated that many of the farmers were managing their ponds better at the end of the Pilot Project. Many of the ponds dominated by *T. Randall* at follow up still had populations of *O. shiranus*. But many of the farmers were in the process of eliminating these fish from the ponds. In many cases, farmers did not return *O. shiranus* caught by the survey team to the ponds, but kept the fish for household consumption.

Change in size frequency distribution

Narrower size distribution and a more uniform distribution of size frequencies about the mode were evidence that many of the farmers were practicing better pond management than they were at the beginning of the Pilot Project. Results implied that farmers were being more careful when stocking the ponds, were removing fingerlings and were applying some level of grading.

Change in food and feeding

The reduction in use of cheap feeds such as madeya (maize bran) and rice bran and the increased use of more expensive feed ingredients such as soya[3] and pellets was a significant development and demonstrated that farmers were willing to invest more in aquaculture than previously and were regarding their fish more as livestock which needed to be fed high quality feeds than as a crop which could merely be fertilized.

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[3] For example, 50kg bag of madeya, rice bran and soya cost approximately MK 100, MK 50-175, and MK 1,250-3,500 respectively.

Table 2.5 Food use

Food item	Madeya	Rice bran	Mash	Greens	Soya	Other	Pellets
Number of farmers at Baseline survey (2004)	25	6	0	23	4	4	0
Number of farmers at Evaluation survey (2005)	23	2	1	18	10	3	3

Source: Baseline survey (2004) and evaluation survey (2005)

Change in use of fish

The decrease of sales to villagers on farms and distribution to family and friends linked with an increase in sales to market, indicated that higher quantity and quality of product was being produced. This product would have received a higher price in more urban markets. It may also have been an indication of a trend toward commercial and away from subsistence aquaculture.

Table 2.6 Use of fish

Use	Household consumption	Distribution to family and friends	Sale to other villagers on farm	Sale to market
Percent use Baseline survey (2004)	13	9	50	24
Percent use Evaluation survey (2005)	18	4	33	36
Percent change	5% increase	5% decrease	17% decrease	12% increase

Source: Baseline survey (2004) and evaluation survey (2005)

<u>Result</u>

The evaluation survey clearly indicates that farmers have high motivation towards learning. Due to the limited timeframe, it was difficult to observe a significant increase in fish production among farmers, but various changes in aquaculture practices were recorded. As to conclude, it is fair to say that innovative farmers are eager to adopt new ideas, and willing to produce more.

2.4.2 Innovative farmer's network leads information and technology transfer among the farmers

<u>Why has this assumption been chosen?</u>

There has not been any network linking fish farmers in Malawi in the past. In the national socio-economic survey on aquaculture implemented by the ADiM Study team in 2003 shows that over 50% of information on fish farming is provided by fisheries extension staff to farmers (Attachment 9). However, as it is described later in this paper, number of fisheries extension staff is limited and not all farmers have frequent access to those extension staff.

In this assumption, we seek the possibility of the network which links fish farmers in all over Malawi to provide a new opportunity for them to exchange information and ideas to enhance their fish farming activities.

<u>How has it been verified?</u>

Information and ideas exchanged during a series of trainings was discussed in the participatory evaluation workshop. The cost shared for the network activities was calculated through monitoring.

Following indicators are used for the verification.

Indicator 1: Amount of information exchanged among farmers

Indicator 2: Cost spent for transportation and communication

Indicator 1: Amount of information exchanged among farmers

The activities of IFFNT in past one year have been the Pilot Project-driven. Yet, active information exchange among innovative farmers was observed during a series of trainings, especially during 'farmer-to-farmer' visits. Information exchanged includes various integrated agriculture methods, pond designing, and other aquaculture techniques. Detailed lists of information exchanged is shown in Table 2.7. Looking at information exchange amongst farmers, over 80% (13 out of 16) of innovative farmers reports that they have gained new information from peer farmers. On the other hand, around 30% (5 out of 16) are listed as 'teachers'. Those 30% are also active learners showing those who teach as well as who learn have high motivation on absorbing new information and ideas.

Table 2.7 Information exchanged among innovative farmers

From whom	Who learnt	Information exchanged	When and how
Mrs. Chavula	Mr. Katengeza	How to get rid of tadpoles using lemons	Reporting of Zambia (during mid-term evaluation WS)
	Mr. Msiska	Pig house, technology which he learnt from Zambia	Reporting of Zambia (during mid-term evaluation WS)
Mr. Msiska	Mr. Mukutumula	Pond layout and general cleanness	Farmer-to-farmer visit (Northern region)
Mr. Kamanga	Mr. Katemango	Planting of maize, Sasakawa system	Farmer-to-farmer visit (Northern region)
	Mr. Chavula	Using feed trays	Farmer-to-farmer visit (Southern region)
	Mr. Mzimba	Chicken kola on the pond and a bell to scare birds	Farmer-to-farmer visit (Northern region)
Mr. Msyali	Mr. Sikepe	Chicken house and compost for banana	Farmer-to-farmer visit (Northern region)
	Mr. Nikoloma	How to take care of chicken for them to produce both eggs and manure	Farmer-to-farmer visit (Northern region)
Dr. Chinkhuntha	Mrs. Chavula	Various crops, which can be feed for fish	National Aquaculture Training (visit to Dr. Chinkhuntha's place)
Mr. Twaibu	Mr. Mhango	His hardworking attitude	Farmer-to-farmer visit (Southern region)
	Mr. Katemango	Planting trees	Farmer-to-farmer visit (Southern region)
Mr. Nikoloma	Mr. Baula Mr. Muhango	How to plant banana	Before the project through personal visit Farmer-to-farmer visit (Southern region)
	Mr. Chavula	Water conservation	Farmer-to-farmer visit (Southern region)
	Mr. Kamanga	Breeding fish in happas and using traps for otters	Farmer-to-farmer visit (Southern region)
	Mr. Sikepe	Bought a trap from him	Farmer-to-farmer visit (Southern region)

Sources: Farmers comments obtained during the Final Evaluation Workshop (March 2005)

Indicator 2: Cost spent for transportation and communication

Communication and transportation cost for innovative farmers to attend a series of trainings shared a big portion of the budget for the Pilot Project. For example, for farmers to participate the 1st National Training Course at Bunda College in Lilongwe District, it cost MK 1,921 in average per farmer for his/her transportation. This is because some come from Chitipa District, at the North end of Malawi, whereas some come from Mulanje District, down South. In addition, the Project shared per diem and accommodation for each farmer.

Majority of farmers possesses neither telephone nor P.O. box. Dispatching the vicinity extension staff to inform farmers about the training also generated cost. We had to think out the cheapest mean to inform farmers e.g. using the community radio.

Result

Though it was not arranged, the Pilot Project provided opportunities for innovative farmers to integrate and they utilised these opportunities to exchange their information and ideas. The network does lead information and technology transfer among the farmers. However, there are several challenges to promote the network including the cost. Those challenges will be discussed in '2.5 Lessons Learned'.

2.4.3 Innovative farmers have an influence on their communities, therefore they promote aquaculture extension

Why has this assumption been chosen?

There is currently 41 aquaculture extension staff in DoF. They are not evenly located to whole nation whether the area has potential for aquaculture or not. 32% of innovative farmers (8 out of 25) did not receive any visit from aquaculture extension staff past one year. Especially for those farmers in the Central region, 6 out of 8 are not being visited by extension staff at all. Again, there are issues of not only lack of resources (e.g. no transportation means to visit framers), but also low motivation among these extension staff. As to evidence the situation, two farmers in Southern region who did not receive any extension service live within a diameter of 5km from the nearest fisheries station.

Looking at such situation of the Government extension system, it is important to think about an alternative extension system in parallel. Under this assumption, we seek possibility of innovative farmers being farmer extensionists or farmer trainers.

How has it been verified?

The questions on innovative farmer's influence on their communities were asked in the socio-economic questionnaire for the evaluation survey. The questions inquire the number of individual visitors, group visitors and number of community members who adopted innovative farmers' technologies. The follow-up interviews with four selected farmers were also referred. The follow-up interviews aimed at obtaining the reputation of each innovative farmer within their community. 16 to 25 farmers who live adjacent to the respective innovative farmer were interviewed.

Following indicators were used for the verification.

Indicator 1: Number of visitors innovative farmers has received

Indicator 2: Perceptions of farmers towards an innovative farmer who live vicinity to their community

Indicator 1: Number of visitors innovative farmers has received

The number of new adopters to technologies initiated by the innovative farmers averaged at 89.5 farmers per innovative farmer. Each innovative farmer is receiving an average of 32.8 individual and 3 group visitors in 2005. We should note that there are big differences in numbers of adopters and visitors among 25 innovative farmers such that standardisation could result in misconception on each farmer's abilities (e.g. the standard deviation for the number of farmers who adopted technologies is 398.3. It is Dr. Chinkhuntha who has projected figure. Without him, the average goes down to 9.9). However, considering all the activities which were carried out by each innovative farmer's own initiative on *ad hoc* basis, they have a huge potential to play a substantial role as an information provider.

Table 2.8 Number of visitors

	Name	2004				2005			
		Group visitors	Individual visitors	Visits	Adopters	Group visitors	Individual visitors	Visits	Adopters
1	Nikoloma	28	500	4	0	7	100	40	50
2	Baula	4	51	2	9	5	10	4	7
3	Twaibu	7	40	3	30	0	6	4	3
4	Binali	6	43	20	30	1	0	4	2
5	Mlemba	2	14	20	40	0	8	6	0
6	Mkaliainga	0	30	0	3	2	0	0	0
7	J. Moyenda	3	12	2	0	1	0	1	0
8	Mkutumula	6	50	0	0	0	14	7	6
9	Matola	4	30	7	5	6	7	20	20
10	Zembere	15	60	3	2	5	100	5	20
11	Kampata	5	20	2	10	1	15	5	25
12	Chokani	0	150	40	40	4	60	11	16
13	Chinkhuntha	40	4,000	2	2,000	12	240	0	2,000
14	Zungulana	6	20	15	20	1	10	2	5
15	Sikepe	7	30	6	12	12	20	3	6
16	Katengeza	10	120	2	2	1	0	0	1
17	Kalembo	5	20	57	57	7	50	0	53
18	Msyali	20	200	5	100	1	50	10	0
19	Ms Msiska	6	100	5	10	1	5	7	9
20	J. Kamanga	2	100	7	4	0	5	6	2
21	Mhango	0	10	8	20	0	0	1	0
22	Ng'ambi	2	0	6	4	0	5	15	0
23	Zimba	0	365	0	2	1	10	0	3
24	Chavula	2	3	75	4	4	100	30	3
25	M.M. Msiska	5	20	14	12	3	5	5	6
	Average	7.4	239.5	12.2	96.6	3.0	**32.8**	7.4	**89.5**
	Average without Chinkhuntha	6.0	82.8	12.6	17.3	2.6	24.2	7.8	9.9
	STD	9.39	792.22	18.61	397.19	3.54	54.27	9.73	398.28

Source: Baseline survey (2004) and evaluation survey (2005)

<u>Indicator 2: Perceptions of farmers towards an innovative farmer who live vicinity to their community</u>

All four innovative farmers selected in the follow-up interviews are well known by their communities (Table 2.8). All are influential in one way or another. Three had good reputation. They interact with their communities and exchange knowledge including those on fish farming. Box 1 describes how Mr. Chokani, one of those three, is perceived by surrounding community members. One innovative farmer, though he was well known, did not have good reputation among his community members.

Table 2.9 Summary of interview to four prominent innovative farmers

	Farmer A	Farmer B (Mr. Chokani)	Farmer C	Farmer D
No. of farmers interviewed	16	23	25	16
No. farmers who are aware of IF	16	19	25	16
No. farmers who have visited IF's farm	16	most of 19	not many (some worked as labourers, some failed to visit due to entrance fee)	16
Major positive opinion given towards IF	-hard working -advanced -worth emulating	-prominent due to practicing integrated/ mixed farming -profitable -admirable and worth emulating	-prominent due to practicing farming with high capital, huge land and hired labour	-prominent due to practicing fish farming -his activities are very good and profitable -he integrates crops, fish and livestock
Major negative opinion given towards IF	non	non	-not very supportive -denies other people access to water -thinks about his own profit	non
Providing info./ equipment	-willing to provide any info. -a few were given fingerlings/ a few purchased fingerlings -learned technologies and tried on their farms -provide job opportunity	-very few received goods for free, but purchase banana suckers & fingerlings -very good info. flow/ majority received info. on farming activities -mobilises a group of farmers	-no one received goods nor information -does not let anybody utilise his technologies but people just deceptively copy some of his technologies	-some farmers received goods & info. (banana suckers & fingerlings) -he provides info. on fish farming, pond construction, and dimba crop production
Contribution to local development	-contributed through farmers' club	-contributed through mobilising of farmers' club -provide initiatives to other farmers	-contributed through introducing irrigation and dimba cropping -facilitate construction of a bridge	-contributed through introduction of vegetable, banana, irrigation & fish farming

Source: Follow-up evaluation survey (2005)

Box 1: Impact of innovative farmers on other farmers within their area of operation
Case of Mr. Chokani

Backgroud
Mr. Chokani is an innovative farmer based in Mchinji District, Mselera Village. Thirteen farmers from Mselera and ten from Benjamin villages in the district were interviewed to find out their knowledge and views about Mr. Chokani's farming activities. Benjamin village is about 12 km from Mselera village.

Results
19 out of the 23 farmers interviewed indicated that they know Mr. Chokani. The respondents indicated that Mr. Chokani is prominent mainly due practicing integrated/mixed farming as well as growing crops throughout the year without necessarily depending on rainfall. Their opinions about his farming activities are that the activities are profitable and earn him more income such that he does not lack anything in his household. Some respondents indicated that his farming activities are admirable and worth emulating only that they cannot afford to buy fertilizer as he does.

The respondents also acknowledged that the farming activities of Mr. Chokani were different from theirs. His farming activities result in high yields and generate more income. Very few farmers have received goods from Mr. Chokani. The goods are mainly banana suckers and fingerlings. However there is very good information flow between Mr. Chokani and other farmers. Most respondents indicated that they received information on various farming activities from Mr. Chokani. The farmers take an initiative to go and ask for information or to observe the farming practices so as to learn. Some go to ask for the information as a group (club) while others as individuals. Mr. Chokani mobilized a group of farmers and assisted them to receive treadle pumps and get training on mushroom production through EU funding. Regarding goods, Mr. Chokani mostly sells his goods to the other farmers. Goods sold include banana suckers and fingerlings.

Technologies that have been introduced from Mr. Chokani include vegetable, rice, banana and irrigated maize farming. Most respondents from Mselera Village indicated that they wished they could adopt fish farming. However, fish farming seems to be too labour intensive and hence labelled it as difficult. Others indicated that they feared that ponds would take over the land for dimba cropping such that they end up not growing dimba crops. However respondents from Benjamin Village indicated that they are more interested in fish farming because it is possible. Others even have the opinion that they can gain more profits from fish farming than tobacco production.

All the respondents that knew Mr. Chokani had an opinion that he had contributed to the development of their area. His contribution is through mobilization of farming clubs that have assisted farmers to acquire treadle pumps and go into irrigation farming. Along with that there are increased yields and incomes such that food security has improved. Through initiatives from Mr. Chokani people work harder and produce more to improve their nutritional and financial status. Some businesses have also improved. People that adopted vegetable farming indicated that they generate more income from vegetable selling. One respondent stated that she has even developed a hawker through capital from vegetable production. There were no negative impacts from Mr. Chokani's farming activities that were reported.

Source: Follow-up evaluation survey (2005)

<u>Result</u>

Innovative farmers in general have a good influence on their communities and contribute greatly towards aquaculture extension as farmer extensionists or 'farmer trainers'. At the same time, it is interesting to notice once one gets more influential, it can cause some friction between him/her and the community. Though only one case has been observed during the Pilot Project, it is worth noting for future planning.

2.5 Lessons Learned

'Does the Innovative Farmer Approach contribute to the Aquaculture Development?'

From the above results, it is assumed that the innovative farmer approach, networking innovative farmers, building their capacity, and facilitate them as "farmer trainer" for promoting local extension service innovative farmers, will promote aquaculture development in Malawi.

During the Pilot Project, innovative farmers networked themselves and registered as "Innovative Fish Farmers Network Trust (IFFNT)". However, they are still immature both as an aquaculture farmer trainer and as an organisation. IFFNT is planning to meet and discuss way forward. However it is difficult for them to sustain without a support from DoF at this stage. Through close collaboration with DoF, **innovative farmers need to recognise IFFNT as THEIR organisation, identify future vision, and prepare and implement the action plan for their future activities**.

Challenges the Pilot Project confronted during its implementation are described below under following topics: a) cost; b) aquaculture extension by innovative farmers; c) exchange of information; and d) contents of capacity building. The countermeasures for future are suggested for the innovative farmer approach to be more effective, efficient, and sustainable.

a) Cost

<u>Challenges</u>

The total budget for the Pilot Project Component 1 was approximately US$49,000. When the figure is evenly divided by 25 farmers, the cost shared for one farmer calculates to US$1,960. In order to evaluate the impact of trainings within the short period, the Pilot Project provided intensive training with qualified information. At the same time, targeting farmers all over Malawi resulted with high transportation, per diem and accommodation cost. The Agricultural Sector Programme Support supported by DANIDA spent about US$60 per person for training farmer trainers. Comparing both figures, the Pilot Project has spent a lot more and it needs to be reviewed when future sustainability is concerned.

<u>Suggestions for future</u>

For its sustainable operation and management, the network needs capital. **The financial source, either through joint collaboration with DoF, fund procurement from donors, or business implementation by the network itself, needs to be sought.**

At the same time, **the network activities will be decentralised and number of national meetings will be minimised**. Cost effective and efficient networking structure needs to be discussed.

b) Aquaculture extension by innovative farmers

<u>Challenges</u>

The activities of the Pilot Project focused on providing various trainings to enhance innovative farmer's capacity. Their ability on extension service was measured through looking at their impact on surrounding communities. There performance was, therefore, more or less on *ad hoc* basis.

<u>Suggestions for future</u>

Under the Agricultural Sector Programme Support, trained farmers have implemented an extension service to an average of 16 farmers in a period of one-week monitoring. Since informal extension service highly depends on farmer's personal ability, **a systematic or structured farmer-to-farmer extension service also needs to be suggested** for further propagating effect.

DANIDA raises limited technical capacity of farmer trainers as one of the challenges. The extension service to be implemented by innovative farmers should have a **close collaboration with government extension staff and NGOs that are active in the area**. The government extension staff can provide technical know-how, where as NGOs are skilled at rural development. The collaboration with other sectors, such as agriculture, health and education, can also enhance the quality of the extension service.

The Pilot Project shows the diversity among innovative farmers not only on their learning capacity but also geographical conditions and styles of aquaculture implementation. When a systematic or structured farmer-to-farmer extension service is to be implemented, this diversification of each farmer needs to be considered and flexibly applied.

c) Exchange of information

Challenges

There are three ways of information exchange when the innovative farmers approach is to be implemented. They are information exchange (1) between the government/ NGO/ the private sector and innovative farmers, (2) among innovative farmers, and (3) between innovative farmers and their fellow farmers.

Because of limited time and resources, the information tended to flow from the JICA Study Team to farmers in one way direction during the Pilot Project. The information exchange among innovative farmers was carried out informally which in result, limited its contents.

Suggestions for future

(1) Between the government/ NGO/ the private sector and innovative farmers

The information between the government/ NGO/ the private sector and innovative farmers tends to flow from the former to the latter if it is done as training. However, farmers should not just receive and accept those information, but think, judge, act, and be responsible by their own. Aquaculture development depends how farmers utilise newly gained information.

(2) Among innovative farmers

Informal information exchange will continuously be encouraged. At the same time, it is important to note that as a farmer is more inclined to be an entrepreneur, he/she tends to select knowledge/ information they share with their colleagues. To maintain high quality information, some rewards should be provided to information providers.

The government can also provide some advises on information to be exchanged among network members.

(3) Between innovative farmers and their fellow farmers

The information exchange between innovative farmers and their fellow farmers will generally be based in their local area. When innovative farmers act as farmer trainers, some rewards for their service need to be considered. Again, fellow farmers should not just receive and accept those information, but think, judge, act, and be responsible by their own.

d) Contents of capacity building

Challenges

Because of limited time and resources, the Pilot Project put more emphasis on the capacity building on technical aspects. However, in the long term, strengthening of not only technical but also other abilities need to be looked into.

Suggestions for future

The areas for the capacity building for future are suggested as follows.

(1) Capacity to think

As it has been stated already, farmers should learn how to think, judge, act, and be responsible by their own.

(2) Capacity on aquaculture and integrated agriculture technology

Technology on not only aquaculture but also integrated agriculture needs to be looked at.

Current fish farmers as well as potential fish farmers are farmers. Through strengthening integrated agriculture technologies, they are able to incorporate aquaculture into their other farming practice which may lead to a synergic effect.

(3) Capacity to manage

For increasing the agricultural productivity, the management skill as well as technical skill is required.

(4) Capacity to negotiate

Farmers need to have a capacity to talk, discuss and negotiate with the government, donors and NGOs on the same platform.

(5) Capacity for the extension

Information needs to be passed onto others. Farmers need to learn how to provide the best extension service as trainers.

Incorporating above suggestions, the innovative farmers approach will surely play an important role in NASP (National Aquaculture Strategic Plan) especially in the field of aquaculture extension.

For its implementation, it is important to monitor periodically, readdress challenges and suggestions and improve the approach based on the lesson learned.

3. Pilot project Component 2 "Farmers' Club Approach"

3.1 Objective

'What is the farmers' club approach?'

The 'Farmers' Club Approach' seeks an effectiveness of targeting small-scale farmers in the clubs for development and extension on small-scale aquaculture system.

The Pilot Project studies two existing farmers' clubs, Mawila and Limbikani farmers' clubs on their collective pond management as well as their activities as clubs. The Project also identifies the role of an NGO, the World Vision Malawi (WVM) as the NGO who initiated those two clubs and seek possibilities for duplicating the successful clubs to the other areas.

3.2 Assumptions for the Verification

Four assumptions were set up in order to verify the feasibility of the farmers' club approach.

The assumptions are:

1. Farmers benefit household stability by being a member of a farmer club,
2. Aquaculture can contribute subsistence farmers in the club,
3. Successful farmer club will be duplicated in the other area, and
4. NGOs contribute towards the aquaculture development.

3.3 How to Verify the Assumptions

In order to verify the above assumptions, the following activities are implemented during the Pilot Project.

1. Identification of farmers' clubs (A. farmers' clubs with collective fish ponds; B. farmers' clubs wishing to start fish farming)
2. Baseline survey
3. Training and visit (needs assessment, training in class room, study tour, farmer-to-farmer visit)
4. On-farm experiment (A. participatory planning, creation of action plans and implementation; B. construction of collective fish ponds)
5. Evaluation (mid-term evaluation, evaluation survey, and final evaluation)

1. Identification of farmers' clubs

Through discussion with WVM and DoF, two farmers' clubs that have 'successfully' implemented fish farming were selected, namely Mawila and Limbikani farmers' clubs[4]. There were other clubs that were nominated as newly established clubs wishing to start fish farming. There are total of ten farmers' clubs which have been involved in the Pilot Project at some stage (Attachment 10)[5]. Together with WVM, the ADiM Study team held a participatory planning workshop with representatives from each club to discuss on a detailed action plan for the Pilot Project.

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[4] The identified farmers' clubs are located in Chingale area, Mlumbe Traditional Authority (TA), Zomba district (its location is shown in Attachment 9). They have been supported by WVM under the Chingale Agricultural Development Programme (ADP). Mawila and Limbikani farmers' clubs have introduced individually owned collective fishponds. They are well maintained and farmers are actively involved in fish farming. Chingale area is one of the poorest areas in Malawi (64.3-70% of population of Mlumbe TA is below the poverty line). Yet, they are managing the fish farming with minimum support from DoF. The JICA Study Team saw them as a 'successful case.'

[5] Attachment 10 shows the level of involvement of each club within the Pilot Project activities.

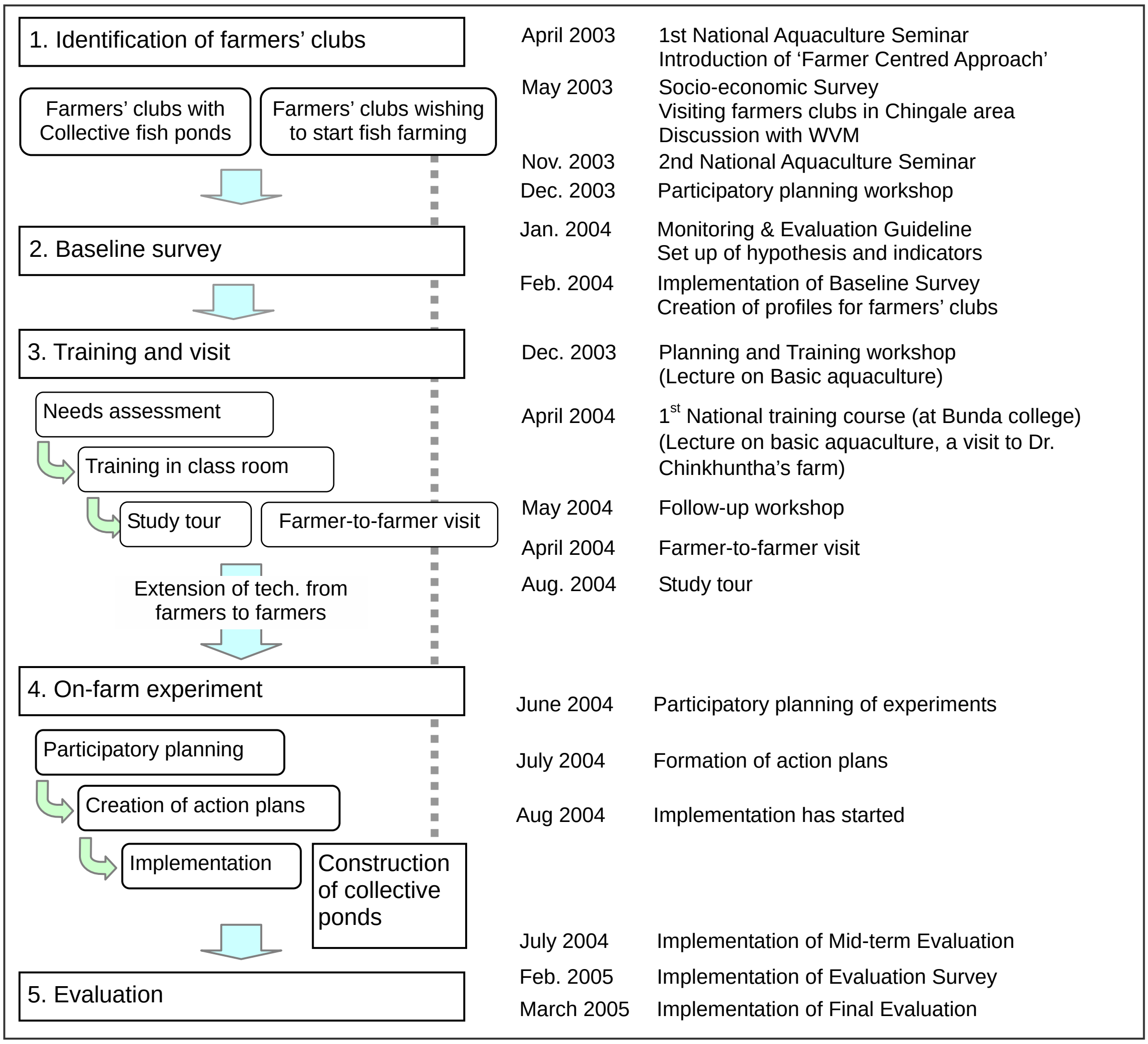


Figure 3.1 Activities of the Pilot Project Component 2 and Achievement

2. Baseline survey

In February 2004, the baseline survey was implemented for two pioneer clubs and four other clubs (Attachment 12). The baseline survey aimed to understand clubs' technical abilities and socio-economic status as well as to identify new clubs to be targeted for the Pilot Project. Further information on those clubs are described in Working Paper 4.

3. Training and visit

The planning and training workshop was held in December, 2003. The workshop provided a basic aquaculture lectures and built consensus with club members on the Pilot Project. The needs assessment was also carried out during the workshop. In April 2004, a training course was held at Bunda college together with innovative farmers. The course included a visit to Dr. Chinkhuntha's farm. For newly established clubs, farmer-to-farmer visit was arranged in April, 2004. In August 2004, representatives of each club participated to the study tour visiting some of innovative farmers' farms and small-scale irrigation sites.

4. On-farm experiment

Based on what has been taught, 3 farmers' clubs (Mawila, Limbikani, and Mkanwalekani farmers' clubs) have implemented on-farm experiments. The outline of the experiments are shown in Attachment 13. One club, Teuka farmers' club, was assisted by the Pilot Project for the construction of collective fish ponds.

5. Evaluation (mid-term evaluation, evaluation survey, and final evaluation)

The mid-term evaluation workshop was implemented in July 2004 and the results were compiled in the report called 'Master Plan Study on Aquaculture Development in Malawi: Field Report The Pilot Project -Mid-term Evaluation-' (2004). In February 2005, the evaluation survey (technical survey and socio-economic questionnaire) was implemented and the participatory evaluation was carried out at each club site. During the period of the Pilot Project, continuous monitoring was carried out by both the ADiM Study team and WVM.

The budget allocated for above mentioned activities was US$ 25,000 (Attachment 14).

The time flow of activities is described in Figure 3.1.

3.4 Results

Four assumptions were verified through various activities implemented during the Pilot Project. The specific indicators used for the verification were listed in the Table 3.1.

Table 3.1 Assumptions, methods for verification, and indicators

Assumptions	Methods for Verification	Indicators
Farmers benefit household stability by being a member of a farmer club	Socio-economic questionnaire for the evaluation survey Key informant interview for the evaluation survey Monitoring	1. Income through collective labour 2. Interaction with outsiders 3. Time spent for club activities
Aquaculture can contribute subsistence farmers in the club	Monitoring and observation Group discussion and key informant interview for the evaluation survey	1. Changes in club activities 2. Benefit of implementing aquaculture by a club
Successful farmer club will be duplicated in the other area	Monitoring Key informant interview	1. Number of clubs duplicated and clubs that had an impact through the Pilot Project
NGOs contribute towards the aquaculture development	Monitoring Key informant interview	2. Activities of WVM (input, project duration, etc.)

Source: Author (2005)

3.4.1 Farmers benefit household stability by being a member of a farmer club

<u>Why has this assumption been chosen?</u>

There are both benefits and costs of being a member of a farmers' organisation or a farmers' club (Noguchi 2003). The benefits are (1) collective economy, (2) improved accessibility to outsiders, and (3) social security. On the other hand, the costs of being a member of a club are (4) opportunity cost and (5) transaction cost.

(1) Collective economy
- collective purchasing power
- group marketing of agricultural products

(2) Improved accessibility to outsiders
- frequent communication with outsiders

- improved accessibility to services from outsiders (trainings, loans, etc.)
- improved bargaining power

(3) Social welfare
- collective labour
- mutual support/ social security
- forum for sharing knowledge

(4) Opportunity cost
- Cost for sharing time and labour for club's activities

(5) Transaction cost
- Cost for sharing time and labour for building consensus among members

Considering the situation above, we verify whether being a club member will benefit household stability of each individual farmer in Chingale area, and if so, identify those benefits.

How has it been verified?

In order to verify the assumption, the indicators listed below were studied through the socio-economic questionnaires and key informant interviews for the evaluation survey.

Indicator 1: Income through collective labour

Indicator 2: Interaction with outsiders

Indicator 3: Time spent for club activities

Indicator 1: Income through collective labour

Members of both Mawila and Limbikani farmers' clubs work together on the club land and collective fish ponds. In 2004, Mawila Farmers Club raised a profit of MK 12,017 from selling vegetables in the club land and used for club activities. They have also cultivated maize in club land and each member received a range of MK 750 to MK 1,750 from its sales. This share from maize composes from 3.5% to 8.2% of their total average annual cash income (MK 21,296) in 2005. They also receive a share of vegetables which they cultivate together.

Indicator 2: Interaction with outsiders

Farmers in clubs in Chingale area benefit, if not anything else, from improved accessibility to outsiders. It is the first condition to be members of the club to be able to access to the loans from WVM. For example, 96.8% of Mawila farmers' club members are obtaining goats on loans provided by WVM as of 2005. This Pilot Project also has targeted club members.

They are also benefiting from improved bargaining power. Both Mawila and Limbikani farmers' clubs have discussed and obtained land from village headmen. Especially Limbikani farmers' club was newly given additional 6,720m^2 of land in 2005.

Table 3.2 Number of days and hours spent for club activities for four clubs in Chingale area

	Mawila*	Limbikani*	Mkamwalekani*	Teuka
Club area (Feb. 2004)	35,715 m^2	25,061 m^2	5,520 m^2	N/A
Club area (Feb. 2005)	36,045 m^2 (including area that is rented, 924 m^2)	31,781 m^2 (including area that is rented, 924 m^2)	5,666 m^2	20,000 m^2 for farming 30,000 m^2 for ponds

Source: Socio-economic questionnaire for the evaluation survey (2005)
*Attachment 15, 16, and 17 show those changes of Mawila, Limbikani and Mkamwalekani farmers' clubs respectively on the site map

Indicator 3: Time spent for club activities

Table 3.3 shows number of days and hours spent for club activities for four clubs in Chingale area. Each club has different duration of hours and days depending on the club's situation. However, given information is subjected to change. For Teuka farmers' club, the working days used to be 5 days a week. However, members thought it was too much and reduced to two days a week. They have also reduced number of hours for club activities during their farming season.

Data obtained from the socio-economic questionnaire for the evaluation survey shows that 6 out of 31 members from Mawila farmers' club in fact feels their commitment to the club is too much. The chairman, however, is willing to discuss with members and come up with hours to be spent for the club which all members feel more comfortable with.

Table 3.3 Number of days and hours spent for club activities for four clubs in Chingale area

	Mawila	Limbikani	Mkamwalekani	Teuka
Meeting	2/month	1/month for all club members, 3/month for committee members (1st planning, 2nd preparatory for club meeting, and 3rd review)	2/month	1/month
Collective Work	3/week Mon. 7:30-16:00; Thurs. 7:30-16:00; Sat. 7:30-16:00	2/week Mon. 14:00-17:00; Thu. 14:00-17:00	3/week Mon. 14:00-17:00; Tue. 7:00-11:00; Wed. 14:00-17:00	2/week (it used to be 5/ week)

Source: Socio-economic questionnaire for the evaluation survey (2005)

Result

Clubs certainly provides substantial benefit for subsistence farmers which they as individuals cannot reach. Though there is a cost, farmers are willing to discuss within themselves to minimise the cost.

3.4.2 Aquaculture can contribute subsistence farmers in the club

Why has this assumption been chosen?

The construction of ponds requires some inputs and often an individual subsistence farmer cannot afford to pay the cost. However, as a club with collective labour, pond construction can be achieved within a short period. Once it is constructed, the maintenance of ponds can be managed by minimum labour of individual farmers and fish farming can further enhance their integrated farming system. Looking at another aspect, construction of ponds and sharing knowledge on aquaculture and integrated farming within a club can consolidate further coherence of the club members.

Considering the situation above, we verify our assumption, whether the aquaculture can contribute subsistence farmers in the club.

How has it been verified?

In order to verify, we look at a synergistic impact on activization of both aquaculture and agriculture activities through observation and evaluation survey. We also look at an actual benefit farmers are receiving from aquaculture through clubs. Indicators used for the verification are listed below.

Indicator 1: Changes in club activities

Indicator 2: Benefit of implementing aquaculture by a club

Indicator 1: Changes in club activities

It is difficult to quantify the correlation between aquaculture and the intensity of the club activities. However, through monitoring, the intervention of the Pilot Project which supported an aquaculture component of the clubs seems to have raised farmers' motivation of club activities as whole. As well as constructing additional ponds with their own initiatives, clubs starting producing compost after coming back from a site visit from Dr. Chinkhuntha's farm. The produced compost is used for both club farm land and collective ponds. Members are started providing manure which they obtained from their livestock to ponds. The average quantity of manure applied to ponds has increased from 32.24kg/year in 2003 to 248.87kg/year in 2004 in Mawila club[6].

Their activities throughout the year are summarised in the table below (change in aquaculture related activities in Table 3.4 and changes in general is Table 3.5). Attachment 15, 16, and 17 show those changes of Mawila, Limbikani and Mkamwalekani farmers' clubs respectively on the site map.

Table 3.4 Change in aquaculture related activities

	Mawila	Limbikani	Mkamwalekani	Teuka
No. of ponds (Feb. 2004)	30	45 were mapped (53 were reported)	6	11
No. of ponds (Feb. 2005)	33 (4 new ponds, 2 were merged)	51 were mapped (6 are new)	9 (2 still need to be filled with water)	22 (11 newly constructed, 11 owned by farmers when joined)
Pond surface area (m^2) (Feb. 2004)	6,786	12,594	876	1,198
Pond surface area (m^2) (Feb. 2005)	7,586	13,794	1,446	3,398

Table 3.5 Changes in activities in general

	Mawila	Limbikani	Mkamwalekani	Teuka
Fish farming	Deepened /constructed /merged ponds Harvested fish	Deepened /constructed ponds Harvested fish	Deepened /constructed ponds Collected stones for irrigation canal inlet Drained ponds and harvest fish	Constructed ponds
Vegetable	Introduced Irish potatoes		Planted winter maize in club land	Planted beans & winter maize in club land
Fruits	Planted 300 bananas around ponds			
Compost	Made some compost and applied	Made some compost and applied	Made some compost and applied	Made some compost and applied
Others	Renovated water canal Gained land	Built a shed Gained land	Started the construction of a kola Renovated water canal Rented land	Gained land

Source: Group discussion with club members for the evaluation survey (2005)

[6] The livestock possession rate has not changed drastically in Mawila farmers' club (12.1 chickens and 2.15 goats per HH in 2004, 11 chickens and 2.65 goats in 2005). An increase of an amount of manure in fish ponds represents their growing interest for fish farming. However, we should also be aware of that the Pilot Project had provided manure for their on-farm experiment.

Indicator 2: Benefit of implementing aquaculture by a club

Implementing aquaculture as a club provide an opportunity for members to sell their products. A number of fingerlings harvested from each pond in Mawila and Limbikani farmers' clubs is small. However once they are gathered, it accumulated to some quantity and they managed to sell those fingerlings to farmers in Tyolo District through WVM. As a result, in Mawila Farmer Club, the members who raised some money from fish farming increased from 19.4% in 2004 to 43.2% in 2005 and the average income from fish farming has doubled from MK 1,736 to MK 3,583. 50% of fish were sold through WVM and 77.5% was sales from fingerlings[7].

Result

Subsistence farmers are rarely able to maximise the opportunities presented by aquaculture, because they do not have the assets or the resources required to sustain potential productivity. However, by forming a group, farmers are able to overcome some of the constraints, such as labour and resource limitations. Supported by WVM, farmers' clubs are benefiting from fish farming as an integral component of rural development.

3.4.3 Successful farmer club will be duplicated in the other area

Why has this assumption been chosen?

Though we have seen that farmers can benefit from the club, if a success of the club is spontaneous, the case in Chingale ADP will remain as an exceptional case and the majority of farmers in Malawi continues to be poor.

Therefore, it is critical to verify whether the successful farmers' club is duplicable in other area for sustainable and extended prosperity of Malawian farmers.

How has it been verified?

In order to verify, we look at clubs those are duplicated during the Pilot Project as well as clubs those had some impact through our intervention. The information was obtained through monitoring and key informant interview.

Indicator 1: Number of clubs duplicated and clubs that had an impact through the Pilot Project

The Pilot Project, aimed at a duplication of the successful farmer clubs, Mawila and Limbikani Farmers Club, to other areas. As a result, one club, Teuka Farmer Club, after visiting Mawila and Limbikani Farmer Clubs and received a series of training, has gained club land from the village headman, constructed 11 new collective ponds with communal labour and initiated fish farming (refer to Table 3.4).

At the same time, the Chingale Integrated Fish Farming Committee (CIFF) initiated by WVM in 2001 activated their activities. The leading actors of CIFF who are also the members of Mawila and Limbikani Farmers Club trained their member clubs with information they have newly gained from the Pilot Project. It is interesting to see that CIFF supports Fikira farmers' club which the Pilot Project initially implemented the baseline survey at, however due to the limitation of the Project technical and financial capacity, had not continued to support. It suggests the Project has an impact on the clubs in Chingale ADP even in indirectly.

Result

A duplication of successful farmers' clubs in the other areas is possible. However, whole process

[7] Collective fish ponds at the farmer club are constructed and supervised by the club, but are basically allocated to individual members for daily maintenance.

requires time, especially with the current Malawian situation. The limited timeframe of the Pilot Project allowed only a part of the process to happen.

3.4.4 NGO contribute towards the aquaculture development

Why has this assumption been chosen?

The aquaculture socio-economic survey implemented by the JICA Study Team in 2003 shows that NGOs play an important role in aquaculture extension especially in the area where the Government extension is scarce. Anderson et al. says despite 80% of the world extension service is still provided by the Government, NGO and the private sector began to take some role in providing the extension service (2003).

In Chingale area, WVM initiated their programme, Chingale ADP (Area Development Programme) in 1997. Within their ADP, they have actively involved an aquaculture component. Considering such situation, we verify the assumption whether NGO contribute towards the aquaculture development.

How has it been verified?

Through monitoring and the key informant interview, activities of WVM are studied (Indicator 1).

Indicator 1: Activities of WVM

WVM has initiated the first phase of Chingale ADP from October 1997 to September 2002. They are currently implementing the second phase which will phase out in 2011. ADP targets approximately 165 villages with the annual budget of US$382,000[8]. CIFF falls under Chingale ADP and therefore is managed in line with other projects under ADP. A WVM development facilitator was assigned to CIFF. Together with committee members consist of farmers, the facilitator actively engages in aquaculture development. CIFF now supports 437 fish farmers in 19 clubs in Chingale area.

Result

Incorporating aquaculture into the programme implemented an NGO with financial and human resources as well as high skills in rural development, can contribute a lot for aquaculture development.

At the same time, we should be aware of limited technical skills of NGO on aquaculture. Ponds constructed under a supervision of the facilitator needs some renovation. To maximise the role of NGO, the cooperation with DoF and other organisation is necessary which will be discussed in the conclusion.

3.5 Lessons Learned

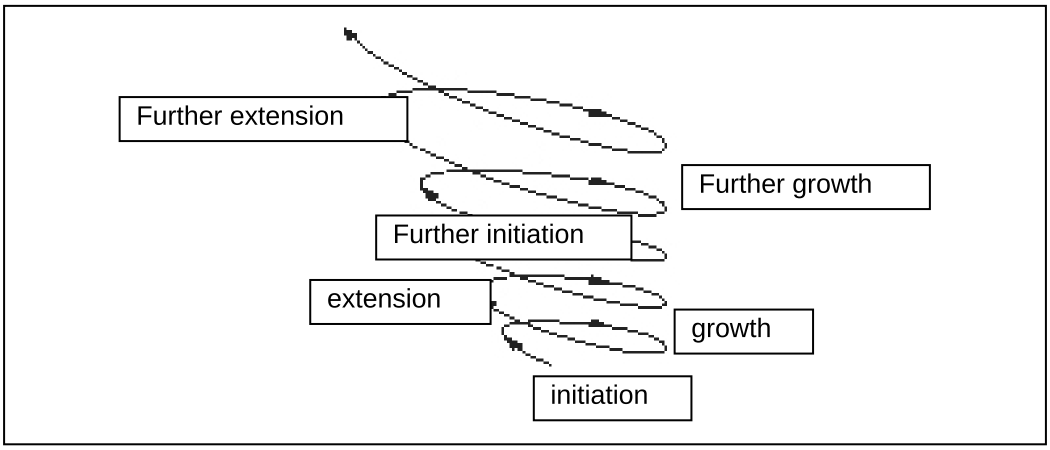
From the above results, it is assumed that through the farmer club approach, subsistence farmers can receive the benefit from aquaculture for their enhancement of their livelihood and therefore, the approach can contribute NASP which aims at poverty reduction by aquaculture development.

Bearing in mind that aquaculture is one of the components of the integrated agriculture which enhances subsistence farmers through the club approach, we now focus our discussion on more general aspects of the approach.

There are three stages for the farmer club approach; namely, the stage of initiation, the stage of

[8] Data was obtained from Mr. Mwendo, the Project Manager for Chingale ADP. Further information is found in the Working Paper 4.

growth, and the stage of extension (refer to the figure below). Once one reaches to the extension stage, the knowledge (including know-how on aquaculture) is passed onto the other group of farmers which again starts the same process.



Source: the author applied an idea from 農村漁家生活改善研究会 (1987:44)

Figure 3.2 Developing stages of the farmer club approach

Initiation and growth of the club

The conditions for the initiation and growth of the club are: (1) farmers' motivation, (2) understanding of the village headman, (3) sustainable support from NGOs, (4) application of farmer-centred approach, (5) time and (6) farming techniques to be applied. From those six conditions, latter four, (3), (4), (5), and (6), are discussed in detail.

(3) Sustainable support from NGOs

Mawila and Limbikani Farmer Clubs were initiated as recipients of loans from WVM in 2001. Since then, WVM has provided not only loans but also a series of trainings which build farmers' capacities. Subsequently, both clubs are now starting their own activities as well as receiving further support from WVM. For subsistence farmers to be mobilised and start activities, such supports from an NGO often holds a key. At the same time, NGOs are not almighty. Through the implementation of the Pilot Project, some institutional weakness of WVM was observed. Mutual monitoring system between farmers and NGOs, or/and peer monitoring system among NGOs can help to optimise their activities.

At the same time, the support will not continue forever. WVM will phase out from Chingale area in 2011. By then, farmers need to be ready to be handed over the baton and be independent.

(4) Application of farmer-centred approach

Mawila and Fikira Farmer Clubs started as a mere recipient of loans from WVM at the beginning. However after few years, there is quite a difference in both attitude as well as activities they carry out. The difference is a clear reflection of how outsiders approach clubs. Fikira Farmer Club was bigger and able to receive continuous donor support which as a result, remained as a support recipient organisation. On the other hand, Mawila Farmer Club, WVM being a major supporter, was exposed to WVM's farmer-centred approach, which built the club more active by their own.

For the future sustainability of the club, building ownership within the club itself is a must. It is often influenced great extent how outsiders approach the clubs, especially at the initial stage.

(5) Time

Enhanced by WVM and other organisations, farmers are actively engaged in various sorts of new activities. Yet, they are still at the trial stage, and time is required to absorb any new technologies/ activities. E.g. in Mawila, more seepage was found after deepening the ponds. They require some time for ponds to accumulate silts at the bottom and settle down.

Learning process requires time. Therefore, when the approach is to be implemented in future, such timeframe needs to be well thought.

(6) Farming techniques to be applied

Because of our intervention, despite our numerous discussions with farmer clubs on the importance of integrated agriculture, their activities past one year were prone to fish farming. It is important to reemphasise that aquaculture is only a component of integrated agriculture, and needs to be integrated with other farming methods.

Draught that attacked Chingale area in the year 2001/ 2002, gave a serious damage to maize. During that period, relish including fish, chicken and goats were sold at low price since everyone was rushing to obtain their staple food, maize. Fish, itself cannot make farmers live though such condition. Aquaculture packaged with the Saving and Credit scheme as well as integrated agriculture will benefit farmers further.

Extension of the club

Once the club is well established, the successful club can be duplicated to the other areas. In order to do so, the actor needs to consider the 6 conditions for initiating and fostering clubs described above. The extension of the club can be further enhanced through collaboration with stakeholders.

Within this framework, aquaculture activities can also be extended through the extension of the club.

For example, in Zomba district, there are several organisations well acquainted with aquaculture; namely Zomba District Fisheries Office, National Aquaculture Centre (NAC) and WorldFish Center. As Zomba district fisheries office is currently establishing an association to coordinate all activities related in aquaculture in Zomba and WVM can play a significant role in aquaculture extension through the Farmer Club Approach.

4. Application of two Approaches to NASP

In the Pilot Project, two approaches, 'Innovative Farmers Approach' and 'Farmer's Club Approach' have been implemented and verified for their applicability for aquaculture development. Both approaches aim at capacity building of fish farmers to play a role in aquaculture rather than being mere receiver of services from DoF. In this Chapter, we look at both approaches within the cotext of the NASP and see how they can contribute to aquaculture research and extension. The table below summarises roles of each approach.

Table 4.1 Summary of two farmers' approaches in aquaculture research and extension

Issues	Potentials		Partners
	Innovative farmers (IF)	Farmers' clubs (FC)	
Research			
Inappropriate research being implemented at NAC.	With high motivation, IFs have willingness to try new thing. Through 'farmer participatory research,' IFs induce more demand driven research to be carried out.		· Innovative farmers · NAC, DoF · External Research Institutions
Lack of study on integration between aquaculture and other agricultural components		FCs with support from NGOs, are aiming at integrated agriculture to enhance their livelihoods. Learning from FCs can contribute tremendously to the research on agriculture integration.	· Farmers' clubs · NGO · NAC, DoF · Bunda College of Agriculture · External Research Institutions
Extension			
Limited number of extension staff	Through 'farmer to farmer extension,' IFs can be farmer trainers working together with aquaculture extension staff. One of the ideas is that IFs to play an important role in 'multi-sectoral farmers' field schools' providing opportunity for other clubs to learn integrated livelihoods approach.	Through 'farmer to farmer extension,' FCs can act as 'multi-sectoral farmers' field schools' providing opportunity for other clubs to learn integrated livelihoods approach.	· Innovative farmers · Farmers' clubs · NGO · NAC, DoF · Bunda College of Agriculture · External Research Institutions · DA
Lack of cross-regional network	IFs have established a network, IFFNT, to link fish farmers throughout the nation. IFFNT can enhance further communication and therefore transfer of knowledge/ information among aquaculture practitioners.		· Innovative farmers · DoF

Source: Author using information obtained from mentoring (2005)

Either to work on the research or extension, the partnership is always important. DoF as taking an initiative, the involvement of farmers from the planning stage will build ownership for playing a role dedicated to them.

As we have already discussed on the main report, together with farmers, other stakeholders also need to be involved in the process of the aquaculture development. They are agricultural extension staff, NGO, research institutions and private sector. DoF needs to identify the role of each actor, and coordinate in the most efficient and effective way that all actors can benefit from such a partnership.

4.1 Research

4.1.1 Current situation and challenges

(1) Inappropriate research being implemented at NAC

In the past years, research implemented at NAC has not been practical in the real situation especially considering socio-economic situation of aquaculture practitioners. It often did not reflect real needs of farmers.

(2) Lack of study on integration between aquaculture and other agricultural components

In order to understand the impact of aquaculture on people's livelihoods, interdisciplinary studies on livelihood approaches is necessary. However, there has not much research been implemented in Malawi.

4.1.2 How can farmers' approach contribute to research?

During the Pilot Project, the innovative farmers have been identified as farmers who can quickly adopt new ideas and are more productive. They know what kind of technologies they wish to try and be further improved. Innovative farmers can, therefore, play an important role in the area of adoptive or exploratory research which requires on-farm experiments. Together with NAC and other external research institutions, the farmers can contribute substantially. **Strategy 2** under the NSAP and the complementary project, 'Chambo research Programme' further explains about such 'farmer participatory research'. The idea is also described in Figure 4.1 as one of the components of farmers' approach in the NASP.

For the enhancement of aquaculture as a component of integrated agriculture, the experiences NGO and farmers' clubs can be utilised. It is further explained in the **Strategy 1**.

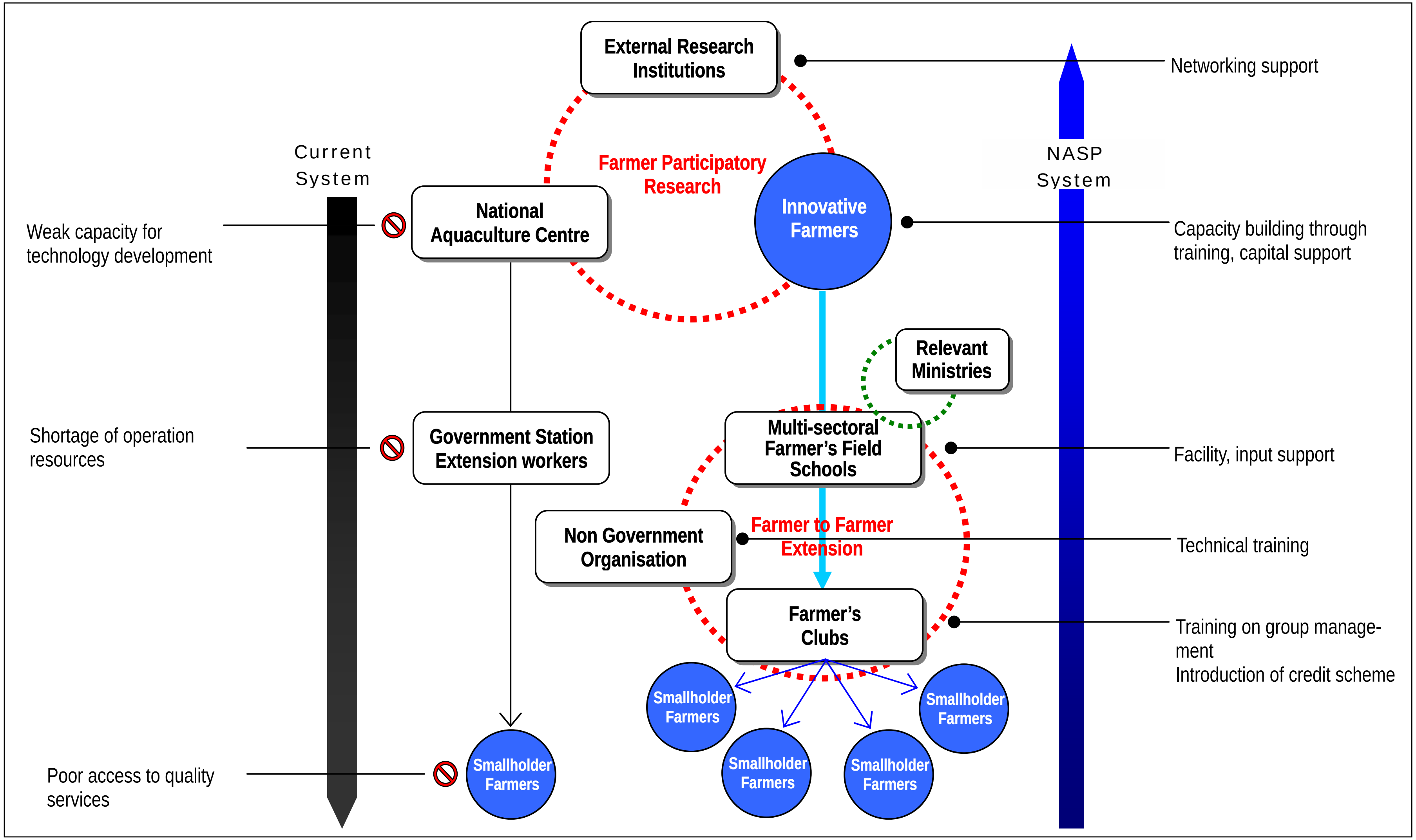


Figure 4.1 Farmers' approaches in the NASP

4.2 Extension

4.2.1 Current situation and challenges

The extension is defined as "the process of introducing farmers to knowledge, information, and technologies that can improve their production, income and welfare (Quizon *et al.* 2001)."

The aquaculture extension, therefore, plays a major role in aquaculture development by introducing farmers to aquaculture knowledge, information, and technologies that can improve their fish production, income and welfare. However, current aquaculture extension in Malawi is mainly dealt by public services and therefore confronts against many challenges. Those challenges are:

- limited human resources with wide coverage area,
- limited financial resources,
- accountability,
- lack of extended knowledge on aquaculture among extension staff,
- low motivation of extension staff, and
- lack of commitment of the Central Government.

(1) Limited human resources with wide coverage area

For aquaculture extension, it is needless to say that the extensionist plays an important role. However the number of DoF extension staff is limited. Currently, there are 41 so-called aquaculture extension staff in whole Malawi. All are scattered from North to South, distributing limited resources thinly which results in weak extension impact in any areas in Malawi.

(2) Limited financial resources

The financial constraint is a common challenge in the most of the public sectors in Malawi. The field of the aquaculture extension is not an exception. However, because it is difficult to trace its impact, and therefore difficult to appeal its importance, the extension tends to be a less powerful claimant for budget.

(3) Accountability

The real needs of farmers are often neglected when the extension service is provided. It is due to the lack of needs assessment of beneficiaries.

(4) Lack of extended knowledge on aquaculture among extension staff

The quality of DoF extension staff is questioned. They are not given enough opportunities to be trained and the materials they have are often not updated. There is also a big gap between research and extension.

(5) Low motivation of extension staff

The low motivation of DoF extension staff is often raised as an issue. With low salary and hard work, extension staff tend to leave extension work till the last.

(6) Lack of commitment of the Central Government

There has been less commitment of the Head Quarters of DoF in extension service despite the fact there are personnel in charge of the extension in the Head Quarters. Lack of communication with poor communication infrastructure is one of the reasons.

4.2.2 How can farmers' approach contribute to extension?

Innovative farmers' approach and farmers' club approach can contribute to the current government extension system through covering some parts in their extension services through 'farmer to farmer extension'. Of course farmers' approaches themselves are not the only solution for existing challenges and most of them explained above needs to be tackled from various directions (Part 1, Chapter IV, Final Report - National Aquaculture Strategic Plan (NASP)-). One of the areas where the farmers' approaches can come into is, as it has been mentioned earlier, the 'farmer to farmer extension' through multi-sectoral farmer's field schools (Figure 4.1). Within the NASP, this idea comes into **Strategy 1**.

Multi-sectoral farmer's field schools

The multi-sectoral farmer's field school[9] is one of the most participatory methods of extension system. Farmers are trained to be the farmer trainers to train other farmers utilising their farms as demonstration farms. It is seasonal and it can be non-formally implemented. It is also important to note that this method puts more emphasis on farmers' capacity building on decision making skills than the adaptation of the high technical skill. Therefore, combining other extension methods with the farmers' field school can further enhance overall impact on the extension system covering a range of target groups with different technical and socio-economic levels. Further suggestions of how the farmer field school to be implemented is described in Attachment 18.

In this way, the effect of the extension where the government extension staff is scarce can be covered by innovative farmers and farmers' clubs. The issue of the limited financial resources is still present for the implementation of the farmers filed school and it needs to be thought through.

Training for trainers

The farmer trainers do lack enough knowledge on aquaculture which can be overcome by providing an appropriate training and setting forward a proper institutional system.

However, in order to enhance farmers' livelihood with acquired aquaculture technology, extension needs to facilitate not only technical aspects, but also an aspect of management. For future farmer trainers, the training for extension methodologies is also important. At the same time, the extension has to aim at empowering target farmers for them to have an ownership in their activities. Farmers need to think, judge, act, and be responsible for the information they receive. Otherwise the extension ends up with mere transfer of information without any impact on aquaculture development. The training on participatory approach (e.g. PRA) and the Community Driven Development (CDD) is therefore necessary.

Possible training course is shown in the table below.

Table 4.2 Possible Training Courses

contents	Trainer
Basic and Extended aquaculture technology	Bunda college/ NAC/ WorldFish Centre
Integrated agriculture technology	Ministry of Agriculture, Irrigation and Food Security (MAIFS)/ Bunda college
Basic business management/ farm management	Bunda college/ MAIFS
Extension methodologies (how to farmer school etc.)	Department of Extension, MAIFS
Participatory approach (e.g. PRA)/ Community Driven Development (CDD)	NGOs

Source: Author using information obtained from mentoring (2005)

Cross-regional network

In the past, there was no network linking fish farmers in Malawi. During the Pilot Project, farmers have established the Innovative Fish Farmers Network (IFFNT) as a first fish farmers' organisation

[9] There are various ways of extension as it is introduced in the main report.

officially registered to the government. As it has been discussed in Chapter 2, though there are challenges, IFFNT does have a potential to link farmers and other stakeholders across the regions and contribute to aquaculture extension. **Strategy 9** in the NASP proposes to support such IFFNT.

Attachment

Attachment 1
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太田美帆（平成 16 年 8 月）生活改良普及員に学ぶファシリテーターのあり方ー戦後日本の経験からの教訓ー、独立行政法人国際協力機構　国際協力総合研究所

野口洋美（2003）農民組織の経済的機能と家計の関わりーエクアドル高地農村部における事例研究からー、「アジア経済」XLIV-7（2003-7）

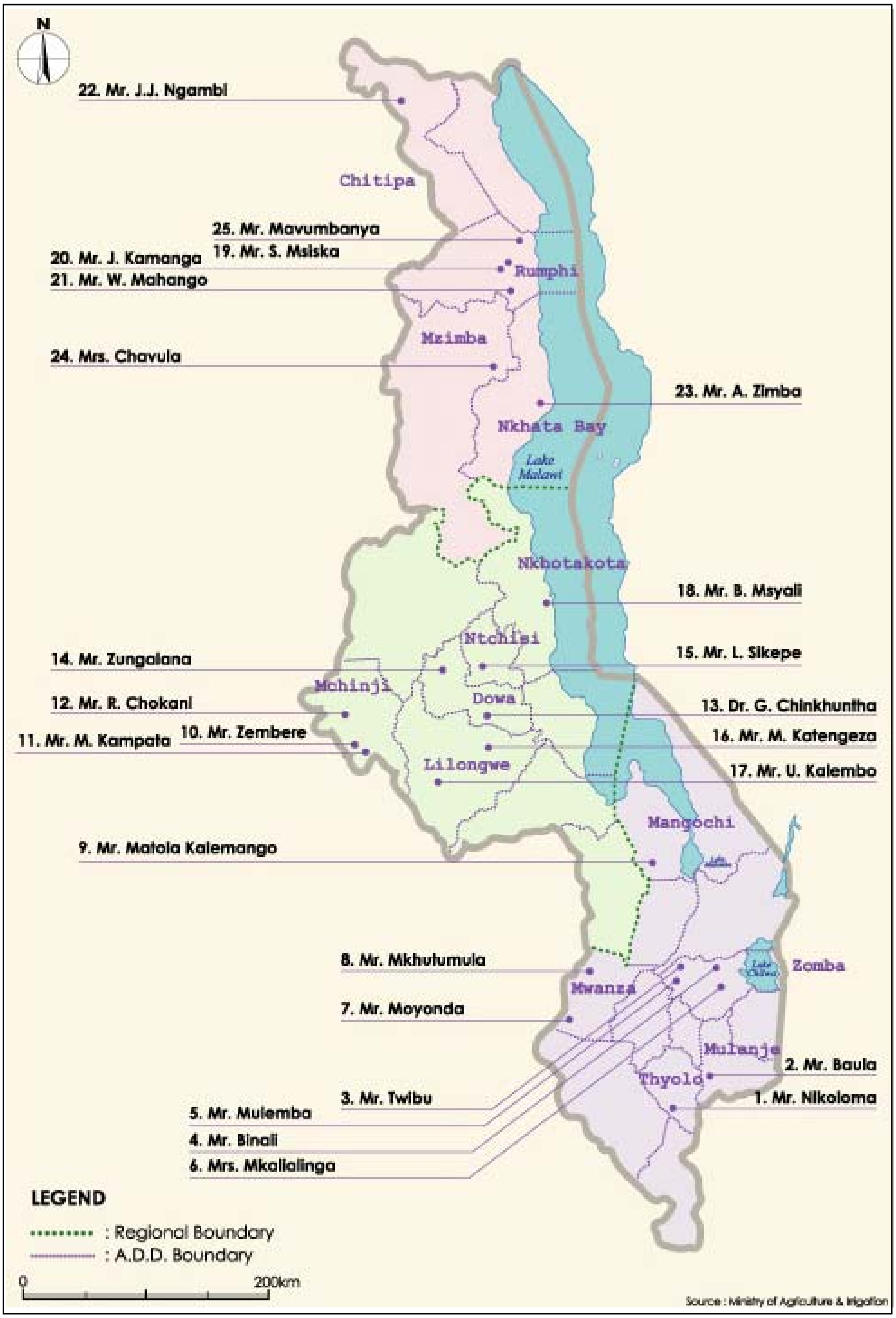
Attachment 2

Names and locations of Innovative Farmers and Fisheries Extension Staff in Charge

	Name	District	TA (Traditional Authorities) SC (Sub-chief Authorities)	Extension Officer Responsible	Affiliation and base
South					
1	Mr. Nikoloma	Thyolo	TA Changata	Mr. Munthali	DoF, Chisitu
2	Mr. Baula	Mulanje	TA Nthiramanja	Mr. Somanje	DoF, Chisitu
3	Mr. Twaibu	Zomba	TA Mlumbe	Mr. Mtegha	DoF, Zomba
4	Mr. Binali	Zomba	TA Malemia	Mr. Bato	DoF, Zomba
5	Mr. Mulemba	Zomba	TA Mlumbe	Mr. Mtegha	DoF, Zomba
6	Mrs. Mkaliainga	Zomba	TA Mwambo	Mr. Bato	DoF, Zomba
7	Mr. Moyenda	Mwanza	TA Nthache	Mr. Malizeni	DoF, Kunenekude
8	Mr. Mkhutumula	Mwanza	TA Dambe	Mr. Malizeni	DoF, Kunenekude
9	Mr. IM Kalemango	Mangochi	TA Chimwala	Mr. Saukani	DoF, Mangochi
Central					
10	Mr. Zembere	Mchinji	SC Mavwere	Mr. Chisale/Sidira	CARD, Mchinji/ DoF LLW
11	Mr. M. Kampata	Mchinji	SC Mavwere	Mr. Chisale/Sidira	CARD, Mchinji/ DoF LLW
12	Mr. Ron Chokani	Mchinji	TA Mlonyeni	Mr. Chisale/Sidira	CARD, Mchinji/ DoF LLW
13	Dr. G. Chinkhuntha	Dowa	TA Mkukula	Mr. Chimangeni	DoF, LLW
14	Mr. Zungalana	Dowa		Mr. Chimangeni	DoF, LLW
15	Mr. L. Sikepe	Nchisi	TA Kalumo	Mr. Katunga	DoF, LLW
16	Mr. M. Katengeza	Lilongwe	TA Chimutu	Mr. Chimangeni	DoF, LLW
17	Mr. U.S. Kalembo	Lilongwe	TA Malili	Mr. Chimangeni	DoF, LLW
18	Mr. B.F.P.K. Msyali	Nkhotakota	TA Malenga Chanzi	Mr. Chizute	DoF, Nkhotakota
North					
19	Mr. S. Msiska	Rumphi	SC Mwahenga	Mr. Lungu	DoF, Nchenachena
20	Mr. J. Kamanga	Rumphi	TA Chikulamayembe	Mr. Lungu	DoF, Nchenachena
21	Mr. W. Mahango	Rumphi	TA Mwankhunikira	Mr. Mkandawa	DoF, Mphompa
22	Mr. J.J. Ngambi	Chitipa	TA Mwenewenya	Mr. Ziyete	DoF, Chisenga
23	Mr. Austin Zimba	Nkhata Bay	TA Mankhambira	Mr. Munthali	DoF, Limphasa
24	Mrs. Chavula	Mzimba	SC Kampingo Sibande	Ms. Msukwa	DoF, Mzuzu
25	Mr. Mavumbanya	Rumphi	TA Kachulu	Mr. Lungu	DoF, Nchenachena

Attachment 3

Names and locations of Innovative Farmers



Attachment 4

Selection Criteria of innovative farmers

- Current, active fish production aimed at the sale of fish
- A level of food security that would allow pond inputs to be available
- Active pond management
- A desire to improve and intensify fish farming operations
- A level of farm integration that allows a variety of farm by-products to be available for pond inputs
- The innovative use of water resources
- A general philosophy of independence rather that one of project dependence

Attachment 5

List of Committee members

Title	Name
Chairperson	Dr. G. Chinkhuntha
Vice chairperson	Mrs. Mkalialinga
Secretary	Mr. M. Katengeza
Vice secretary	Mrs. Chavula
Treasurer	Mr. R. Chokani
Vice Treasurer	Mr. J. N'gambi
Publicity secretary	Mr. Mshali
Committee members	Mr. F. Nikoloma Mr. C. Zembere Mr. U. Kalembo

Attachment 6

Innovative farmers engaged in ADiM's activities

Region		SOUTH									CENTRAL									NORTH						
No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Name		[illegible]	Mr Banda	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ms Rose Chokani	Dr G. C. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
District		Thyolo	Mulanje	Zomba	Zomba	Zomba	Zomba	Mwanza	Mwanza	Mangochi	Mchinji	Mchinji	Mchinji	Dowa	Dowa	Ntchisi	Lilongwe	Lilongwe	Nkhotakota	Rumphi	Rumphi	Rumphi	Chitipa	Nkhata Bay	Mzimba	Rumphi
1. Identification of innovative farmers																										
1st National Aquaculture Seminar	April, 2003	1		1			1	1	1		1		1	1			1	1		1	1				1	
Visiting farmers for short listing	Nov. 2003	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2nd National Aquaculture Seminar	Nov. 2003	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
2. Creation of farmers' network																										
Creation of Innovative Fish-Farmers Network	Jan. 2004	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	
3. Training and visit																										
Participation planning workshop & implementation of needs assessment	Dec. 2003	1	1	1	1	1	1	1	1	1	1	1	1	0.5		1	1	1	1	1	1	1	1	1	1	1
1st National training course (at Bunda college)	April, 2004	1		1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1
2nd National training course (at Bunda college)	July, 2004	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	
Study tour to Egypt (selected members)	June, 2004	1									1		1	1		1			1			1			1	
Study tour to Zambia (selected members)	June, 2004				1		1			1													1			
Study tour to Japan (selected member)	June, 2004																1									
Farmer-to-farmer visit (South)	Oct. 2004	1	1	1	1	1		1	1		1					1				1	1	1	1		1	1
Farmer-to-farmer visit (North)	Dec. 2004	1	1	1	1		1	1	1	1	1	1		1		1			1	1	1	1	1	1	1	
4. Farmers' small project																										
Submission of 1st proposal	May, 2004	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
1st Evaluation	June, 2004	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
1st Selection	June, 2004	1			1		1	1	1	1			1	1		1	1		1	1	1		1		1	
Preparation of work plan	July, 2004	1			1		1	1	1	1			1	1		1	1		1	1	1		1		1	
Procurement of equipment & fingerlings	Aug. 2004	1			1		1	1	1	1			1	1		1	1		1	1	1		1		1	
Submission of 2nd proposal	Aug. 2004		1	1		1					1	1			1							1		1		
2nd Evaluation	Dec. 2004		1	1		1					1	1			1							1		1		
2nd Selection	Dec. 2004		1	1		1					1	1			1							1		1		
Preparation of work plan	Feb. 2005		1	1		1					1	1			1							1		1		
Procurement of equipment & fingerlings	March, 2005		1	1		1					1	1			1							1		1		
5. Evaluation																										
Implementation of Baseline Survey	Feb. 2004	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Implementation of Mid-term Evaluation WS	July, 2004	1		1	1	1	1		1	1	1	1	1	0.5	1	1	0.5	0.5			1	1	1	1	1	0.5
Implementation of Evaluation Survey	Feb. 2005	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Implementation of Final Evaluation WS	March, 2005	1	1	1	1	1		1	1	1			1			1	1			1	1	1		1	1	
1 = full participation																										
0.5= partial participation due to other engagement																										
Participation in activities																										
General training and meeting		11	8	10	11	9	9	10	11	10	9	8	9	7.5	2	11	7.5	5.5	8	10	11	10	10	9	11	5.5
Study tour participants		1	0	0	1	0	1	0	0	1	1	0	1	1	0	1	1	0	1	0	0	1	1	0	1	0
Small project Phase 1		1	0	0	1	0	1	1	1	1	0	0	1	1	0	1	1	0	1	1	1	0	1	0	1	0
Small project Phase 2		0	1	1	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0
% in participation		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Attachment 7

Small projects implemented by 15 farmers (1st round)

1. Mr. F. Nikoloma
(43)
Committee member
Tyolo, South region

Total Farm Area: 3 ha
Major on-farm resources: Cow (6), Poultry (75)
Experience in Fish farming: 19 years
No. of Ponds: 9 ponds
Total size of ponds (Average size of ponds): 1,359m^2 (150m^2)

Small project

- **Fingerling production technology of indigenous tilapia (*O. karongae*)**
- **Fingerling marketing strategy**

To raise *O.karongae* broodstock to supply fingerlings to other farmers, to promote integrated fish farming, to demonstrate to other farmers good farming practices.

4. Mr. Binali
(58)
Zomba,
South region

Total Farm Area: 2 ha
Major on-farm resources: Poultry (10)
Experience in Fish farming: 20 years
No. of Ponds: 5 ponds
Total size of ponds (Average size of ponds): 2293m^2 (458m^2)

Small project

- **Vegetable/maize-fish integrated farming technology**

To investigate superior feeding regime between vegetables and madeya in fish production

6. Mrs. Mkaliainga
(64)
Zomba,
South region

Total Farm Area: 7 ha
Major on-farm resources: Cow (4), Goat (5), Poultry (20)
Experience in Fish farming: 26 years
No. of Ponds: 2 ponds
Total size of ponds (Average size of ponds): 820m^2 (410m^2)

Small project

- **Chicken/Duck/Goat-fish integrated farming technology**

To integrate fish farming with different types of livestock (goats, chicken) as source of manure, increase income and feed availability for fish

7. Mr. Moyenda
(69)
Mwanza,
South region

Total Farm Area: 8 ha
Major on-farm resources: Goat (9), Poultry (10)
Experience in Fish farming: 22 years
No. of Ponds: 2 ponds
Total size of ponds (Average size of ponds): 853m^2 (427m^2)1

Small project

- **The use of alternative on farm resources as fish feeds**

To examine the use and value of alternative on farm resources such as cowpeas, beans and groundnuts as fish food to enhance fish growth and production.

8. Mr. Mkutumula (69)
Mwanza,
South region

Total Farm Area: 6 ha
Major on-farm resources: Poultry (35)
Experience in Fish farming: 19 years
No. of Ponds: 12 ponds
Total size of ponds (Average size of ponds): 1845m^2 (154m^2)

Small project

- ***Tilapia rendalii* -vegetable integrated farming technology**

The best vegetable feed to *rendalli* production will be known

9. Mr. Kalemango Matola (55)
Mangochi,
South region

Total Farm Area: 6 ha
Major on-farm resources: Poultry (10)
Experience in Fish farming: 5 years
No. of Ponds: 6 ponds
Total size of ponds (Average size of ponds): 1126m^2 (188m^2)

Small project

- **Chicken/Duck-fish integrated farming technology**

Productive use of bio-resources in integrated farming as a means o cost reduction experimented

12. Mr. R. Chokani (47)
Treasurer
Mchinji, Central region

Total Farm Area: 13 ha
Major on-farm resources: Goat (2), Poultry (200)
Experience in Fish farming: 6 years
No. of Ponds: 17 ponds
Total size of ponds (Average size of ponds): 11,354m^2 (667m^2)

Small project

- **Pig-fish integrated farming technology**
- **Fingerling production technology of indigenous tilapia**

To develop a basis for sustainable fish farming by using demonstrated technologies which are cost-effective-improved fingerling supply, develop feeding technologies, promotion of linkages, enrich information base for farmer to farmer extension

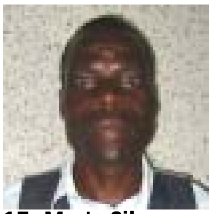
13. Dr. G. Chinkhntha
(60)
Chairperson
Dowa, Central region

Total Farm Area: 20 ha
Major on-farm resources: Poultry (206)
Experience in Fish farming: 9 years
No. of Ponds: 7 ponds
Total size of ponds (Average size of ponds): 2,109m^2 (301m^2)

Small project

- **Pen/cage -cum-pond culture technology**
- **Pig-fish integrated farming technology**

To intensify fish production through intensive feeding in cages with concentrated feeds supplemented with high energy animal manure from poultry and piggery, facilitate programmed production for the market, saving on feeds in as much as only those caged fish will be subjected to intensive feeding, facilitate isolation, monitoring, interpond transfer and harvesting, enhance on farm research and extension service, maximising returns through minimising waste on account of integration and protection of fish from predators, ease of management and capability for graduating to commercial production



15. Mr. L. Sikepe
(49)
Ntchisi,
Central region

Total Farm Area: 3.5 ha
Major on-farm resources: Cow (10), Goat (12), Poultry (12)
Experience in Fish farming: 18 years
No. of Ponds: 4 ponds
Total size of ponds (Average size of ponds): 991m^2 (248m^2)1

Small project

- **Chicken-fish integrated farming technology**

More fingerlings will be produced and fingerling production techniques will be promoted among small scale fish farmers

16. Mr. Katengeza
(33)
Lilongwe,
Central region

Total Farm Area: 13.76 ha
Major on-farm resources: Poultry (400)
Experience in Fish farming: 9 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 954m^2 (318m^2)

Small project

- **Integration of pig farming with *T. rendalli (TR)* monoculture and polyculture of *Clarias gariepinus (CG)*/*O. shiranus (OS)*, and *TR/OS***

1. To maximize economic returns from pig farming
2. Optimise fish production using on-farm resources by integration
3. Compare economic returns of fish under monoculture and polyculture conditions

18. Mr. B. Msyali
(46)
Nkhotakota,
Central region

Total Farm Area: 13.76 ha
Major on-farm resources: Poultry (400)
Experience in Fish farming: 9 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 954m^2 (318m^2)

Small project

- **Cow-fish integrated farming technology**

To know or search which is better than the other for the best result in *rendalli* production between cattle & chicken manure, organic & inorganic fertiliser, in integrated aquaculture-agriculture

19. Mr. Msiska
(61)
Rumphi,
North region

Total Farm Area: 15 ha
Major on-farm resources: Goat (7), Poultry (22)
Experience in Fish farming: 15 years
No. of Ponds: 6 ponds
Total size of ponds (Average size of ponds): 2,790m^2 (465m^2)1

Small project

- **Effect of different feeds and pond depth on fish production**

The project aims to improving growth and production of *T.rendalli* and *C.gariepinus.*

20. Mr. Kamanga
(47)
Rumphi,
North region

Total Farm Area: 5 ha
Major on-farm resources: Poultry (20)
Experience in Fish farming: 18 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 820m^2 (274m^2)1

Small project

- **Effect of pond depth on fish growth and production**

The project will focus on increasing production by comparing three scenarios – deep pond *T.rendalli* monoculture, cf. deep pond polyculture of *O.shiranus* and *T.rendalli* , cf., shallow pond polyculture of *O.shiranus* and *T.rendalli* .

22. Mr. J. Ng'ambi
(51)
Committee member
Chitipa, North region

Total Farm Area: 4 ha
Major on-farm resources: Poultry (40)
Experience in Fish farming: 10 years
No. of Ponds: 8 ponds
Total size of ponds (Average size of ponds): 1,275m^2 (159m^2)

Small project

- **Water fertilization technology by organic & inorganic manure**
- **Feeding technology for *T.rendalii***

To experiment with organic manure, inorganic fertiliser, green compost, vegetable feed to *rendalli*, madeya (maize bran) feed to *shiranus* and local river fish

24. Mrs. Chavula
(31)
Mzimba,
North region

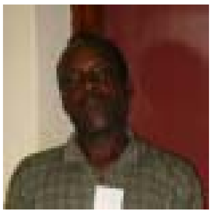
Total Farm Area: 10 ha
Major on-farm resources: Goat (4), Poultry (500)
Experience in Fish farming: 4 years
No. of Ponds: 2 ponds
Total size of ponds (Average size of ponds): 700m^2 (442m^2)1

Small project

- **Pig-fish integrated farming technology**

To find high yielding feeding method of *rendalli* between vegetables & manure application vs manure application only to ponds

Small projects implemented by 8 farmers (2nd round)



2. Mr. Baula
(43)
Mulanje, South region

Total Farm Area: 2 ha
Major on-farm resources: Cow (1), Goat (6), Poultry (13)
Experience in Fish farming: 24 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 708m^2 (236m^2)

Small project

- ***T. rendalli* production using potato leaves**

The project aims to increase production of *T. rendalli* production through best feed practices using potato leaves.

3. Mr. Twaibu
(81)
Zomba, South region

Total Farm Area: 4 ha
Major on-farm resources: Goat (5)
Experience in Fish farming: 33 years
No. of Ponds: 10 ponds
Total size of ponds (Average size of ponds): 2,467m^2 (247m^2)1

Small project

- **Effect of pond depth on fish production**

The project aims to test the difference in growth and production of *O. shiranus (or O .karongae)* and *T. rendalli/ O. shiranus* (or *O. karongae*) in deep and shallow ponds, with *C. gariepinus*.

5. Mr. Mulemba
(86)
Zomba, South region

Total Farm Area: 16 ha
Major on-farm resources: Poultry (5)
Experience in Fish farming: 59 years
No. of Ponds: 6 ponds
Total size of ponds (Average size of ponds): 4,789m^2 (798m^2)

Small project

- **Improved *T. rendalli* and *O. karongae* fingerling production**

The aim of this project is to enhance *T. rendalli* and *O. karonage* fingerling production capacity, since his pond layout provides suitable infrastructure for broodstock rearing and fingerling production for both species.

10. Mr. Zembere
(39)
Committee member
Mchinji, Central region

Total Farm Area: 10 ha
Major on-farm resources: Cow (1), G1oat (11), Poultry (16)
Experience in Fish farming: 4 years
No. of Ponds: 5 ponds
Total size of ponds (Average size of ponds): 1,721m^2 (344m^2)

Small project

- **Controlled breeding of *T. rendalli* and testing natural and artificial feeds**

1. To set up and develop *T. rendalli* fingerling production system in happas to improve fingerling production.
2. To compare fish production (*T. rendalli and O. shiranus*) using artificial and natural feeds.

11. Mr. Kampata
(64)
Mchinji, Central region

Total Farm Area: 3.5 ha
Major on-farm resources: Cow (3), Poultry (30)
Experience in Fish farming: 20 years
No. of Ponds: 4 ponds
Total size of ponds (Average size of ponds): 1,359m^2 (340m^2)1

Small project

- **Growth and production of *O. shiranus* under best feeding**

To assess the effect of optimal feeding (madeya, soya, pigeon pea flour) and manuring on growth of *O. shiranus* under local conditions.

14. Mr. Zungalana
(42)
Dowa, Central region

Total Farm Area: 7.5 ha
Major on-farm resources: Cow (6), Goat (5), Poultry (20)
Experience in Fish farming: 6 years
No. of Ponds: 1 ponds
Total size of ponds (Average size of ponds): 966m^2 (966m^2)1

Small project

- **Use of heavily fertilized pond water for vegetable farming**

Use of heavily fertilized pond water for vegetable farming since the farmer has one large pond under polyculture (*O. shiranus, T. rendalli and C. gariepinus*), which he is able to fertilise intensively using cattle manure.

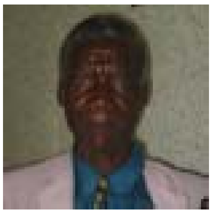
21. Mr. W. Mahango
(54)
Rumphi, North region

Total Farm Area: 20 ha
Major on-farm resources: Goat (3), Poultry (68)
Experience in Fish farming: 2 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 620m^2 (206m^2)

Small project

- **Comparison of production – *T. rendalli* monoculture vs. *O. shiranus* and *T. rendalli* polyculture**

The project will focus on increasing production by comparing two scenarios – *T. rendalli* monoculture, cf. polyculture of *O. shiranus* and *T. rendalli* under optimal local feeding and manuring conditions.



23. Mr. Zimba
(62)
Nkhata Bay,
North region

Total Farm Area: 18 ha
Major on-farm resources: non
Experience in Fish farming: 2 years
No. of Ponds: 3 ponds
Total size of ponds (Average size of ponds): 1,306m^2 (435m^2)1

Small project

- **Growth and production of wild versus station fingerlings**

Compare growth and production of wild fingerlings to station fingerlings. The aim of the project is to compare growth of wild fingerlings to station fingerlings. Farmer initiated this idea himself in 2002 and has shown good results. He now wishes to improve growth of the fish and this must be encouraged.

Attachment 8

Budget for Pilot Project Component 1

	Activities	Cost (US$)
(1)	**Identification of innovative farmers**	**500**
(2)	**Creation of farmers' network**	**2,600**
(3)	**Training and visit**	**25,920**
	National training course	1,540
	Study tour	18,600
	Farmer to farmer visit	5,780
(4)	**Farmers small project**	**10,000**
(5)	**Evaluation**	**9,980**
	Monitoring and evaluation guideline	550
	Baseline survey	8,330
	Mid-term and final evaluation	1,100
TOTAL		**49,000**

Attachment 9

Sources of information for fish farming by category (% of respondents per category per source of information)

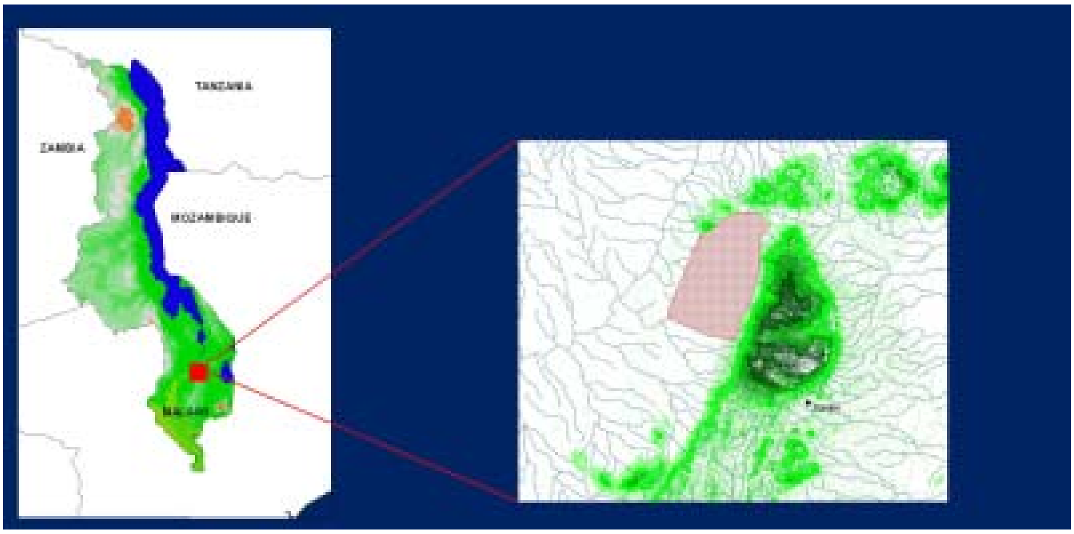
Status	No Harvest	0-19	20-59	60+	New	Ex Fish farmer	Average
Family member	6.3	5.7	8.5	20	4.5	5.9	8.5
Neighbours	30.4	24.1	31.9	40	9.1	5.9	23.6
Observation	34.2	42.4	44.7	25	31.8	26.5	34.1
Farmers club	21.5	13.9	21.3	25	13.6	0	15.9
Extension	57	52.2	72.3	70	63.6	29.4	**57.4**
Project	16.5	28.2	14.9	25	27.3	0	18.7
Reading material	0	2	6.4	0	4.5	0	2.2
Radio	25.3	22	31.9	40	9.1	2.9	21.9
School	3.8	2.4	0	5	9.1	2.9	3.9
Training	13.9	14.3	34	30	13.6	2.9	18.1

Source: ADiM Working Paper 3

Attachment 10

List of clubs in Chingale ADP

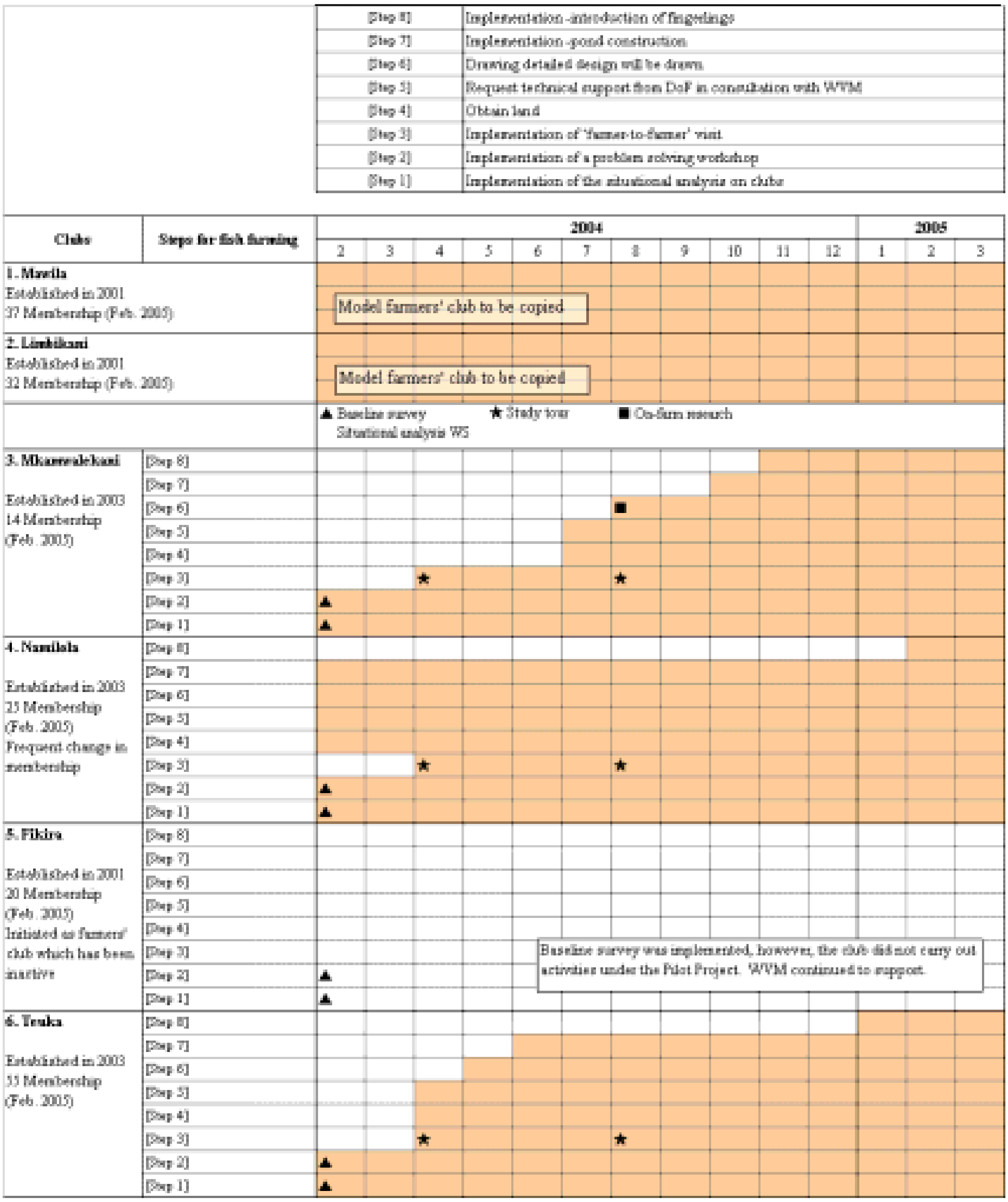
	Names of the clubs	Status on fish farming
1	Mawila	Ponds already established
2	Limbikani	Ponds already established
3	Teuka	Ponds newly established
4	Mkamwalekani	Ponds newly established
5	Namilola	Ponds newly established
6	Fikira	Ponds newly established
7	Nakatope 1	Wishing to establish ponds
8	Nakatope 2	Wishing to establish ponds
9	Chombe 1	Wishing to establish ponds
10	Mlemba	Wishing to establish ponds



Location of Chingale ADP (L.Scott, 2004)

Attachment 11

Process of Pilot Project Component 2



Clubs	Steps for fish farming	2004											2005		
		2	3	4	5	6	7	8	9	10	11	12	1	2	3
7. Nakatope 1	[Step 8]														
	[Step 7]														
Established in 2004	[Step 6]														
14 Membership (May 2004)	[Step 5]														
HIPC pond was constructed in the past	[Step 4]					Situational analysis and problem solving WS was implemented, however, the club did not carry out activities under the Pilot Project.									
	[Step 3]														
	[Step 2]				▲										
	[Step 1]				▲										
Clubs	**Steps for fish farming**	**2004**											**2005**		
		2	3	4	5	6	7	8	9	10	11	12	1	2	3
8. Nakatope 2	[Step 8]														
	[Step 7]														
Established in 2004	[Step 6]														
23 Membership (May 2004)	[Step 5]														
HIPC pond was constructed in the past	[Step 4]					Situational analysis and problem solving WS was implemented, however, the club did not carry out activities under the Pilot Project.									
	[Step 3]														
	[Step 2]				▲										
	[Step 1]				▲										
9. Chembe 1	[Step 8]														
	[Step 7]														
Established in 2003	[Step 6]														
17 Membership (May 2004)	[Step 5]														
Does not implement aquaculture, WVM works together on agriculture	[Step 4]					Situational analysis and problem solving WS was implemented, however, the club did not carry out activities under the Pilot Project.									
	[Step 3]														
	[Step 2]				▲										
	[Step 1]				▲										
10. Mlemba	[Step 8]														
	[Step 7]														
Established in 2001	[Step 6]														
20 Membership (Feb. 2005)	[Step 5]														
	[Step 4]														
	[Step 3]														
	[Step 2]										▲				
	[Step 1]										▲				

Attachment 13

On-farm research for three farmers' clubs in Chingale ADP

Mawila farmers' club

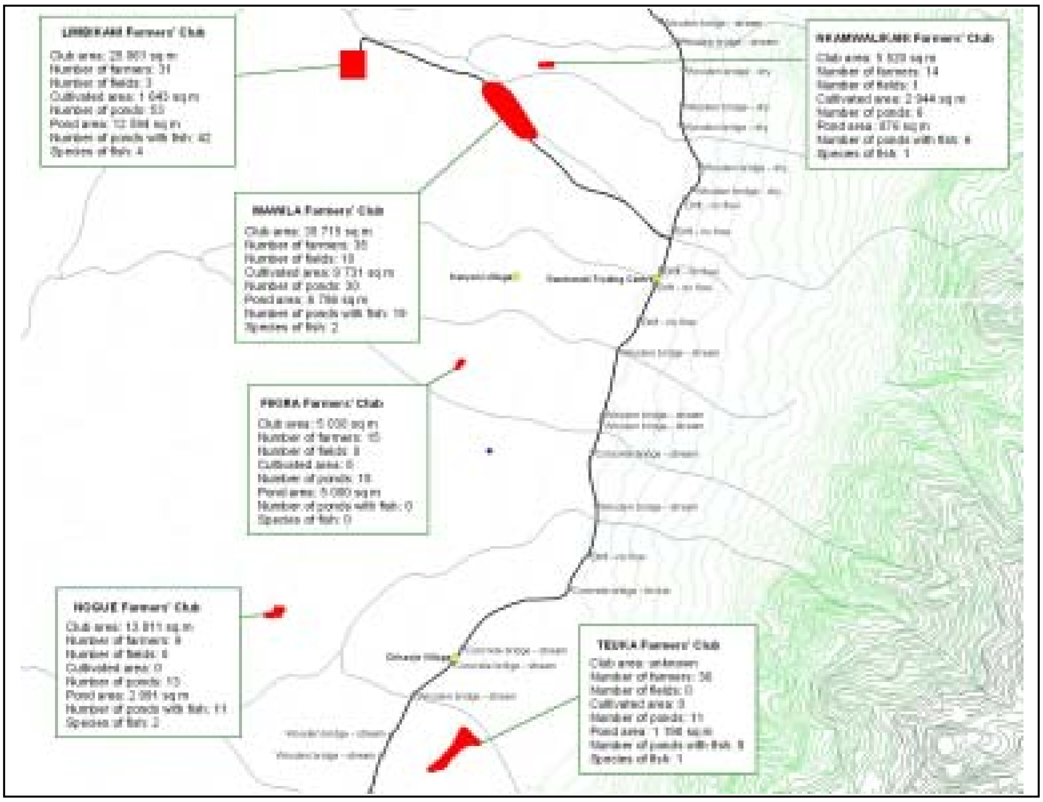
1. Project title: *Tilapia rendalli* production and *O. karongae* broodstock population.
2. Sub-projects:
   (i) Establish *T.rendalli* broodstock population
   (ii) Establish best feeding practices for increased *T.rendalli* production in ponds
   (iii) Establish *O.karongae* broodstock population
3. Project period: August 2004 to end May 2005
4. Objectives: To establish Mawila Club as a centre for *T.rendalli* production.
5. Justification:
   a. *T.rendalli* was identified as the most preferred candidate species by club members.
   b. Pond fertilization techniques were identified as the 2nd most important need of the club
   c. The club has the necessary pond infrastructure and resources to undertake this project.
6. Expected outputs:
   a. Controlled production of *T.rendalli* fingerlings.
   b. Increased *T.rendalli* yield from ponds.
   c. Most economic on-farm practices for enhanced fish production.

Limbikani farmers' club

1. Project title: *O. karongae* broodstock rearing, and improved production of *T. rendalli* and *C. gariepinus*.
2. Sub-projects:
   (i) Establish high quality *O.karongae* broodstock population
   (ii) Establish best feeding practices for increased *T.rendalli* production in ponds
   (iii) Increase growth and production of *C gariepinus* in ponds through polyculture with *O.shiranus*
3. Project period: August 2004 to end May 2005 (broodstock rearing to continue after this)
4. Objectives: To establish Limbikani as a regional producer of *O. karongae* fingerlings, and to improve production practices for *T. rendalli* and *C. gariepinus*.
5. Justification:
   a. O.karongae was identified as the most preferred candidate species by club members.
   b. Club members also expressed a high interest in improving growth performance of T. rendalli and C. gariepinus, and have some experience with the latter two species.
   c. There is currently inadequate supply of O.karongae fingerlings in the region.
   d. The club has the necessary pond infrastucture and resources to undertake this project.
6. Expected outputs:
   a. Production of good quality *O.karongae* broodstock
   b. Increased *T.rendalli* yield from ponds.
   c. Rearing practices for *C gariepinus* established on the farm.

Attachment 12

Location of six Farmer Clubs



Source: L.Scott (2004)

Mkamwalekani farmers' club

1. Project title: *T. rendalli* broodstock rearing and production of *T. rendalli* under monoculture and polyculture conditions with *O.shiranus*
2. Sub-projects:
   (i) Establish best practice for *T. rendalli* production under monoculture conditions and polyculture with *O.shiranus*
   (ii) Establish a high quality *T.rendalli* broodstock population
3. Project period: August 2004 to end May 2005 (broodstock rearing to continue after this)
4. Objectives: To develop Mkamwalekani into a *T. rendalli* production unit
5. Justification:
   a. *T. rendalli* was identified as the most preferred candidate species by club members.
   b. The club will be able to provide a portion of the fingerlings of both species required for the experiments.
   c. The club has relatively few ponds but enough of similar size to allow comparison between treatments.
   d. The club members have land available to increase pond numbers and to grow food for fish. They need the information that will come from these experiments to decide how they will use these proposed ponds in the future.
6. Expected outputs:
   a. Increased *T.rendalli*/ *O.shiranus* yield from ponds.
   b. Production of good quality *T. rendalli* broodstock.
   c. Potential to supply good quality *T. rendalli* fingerlings to other farmers

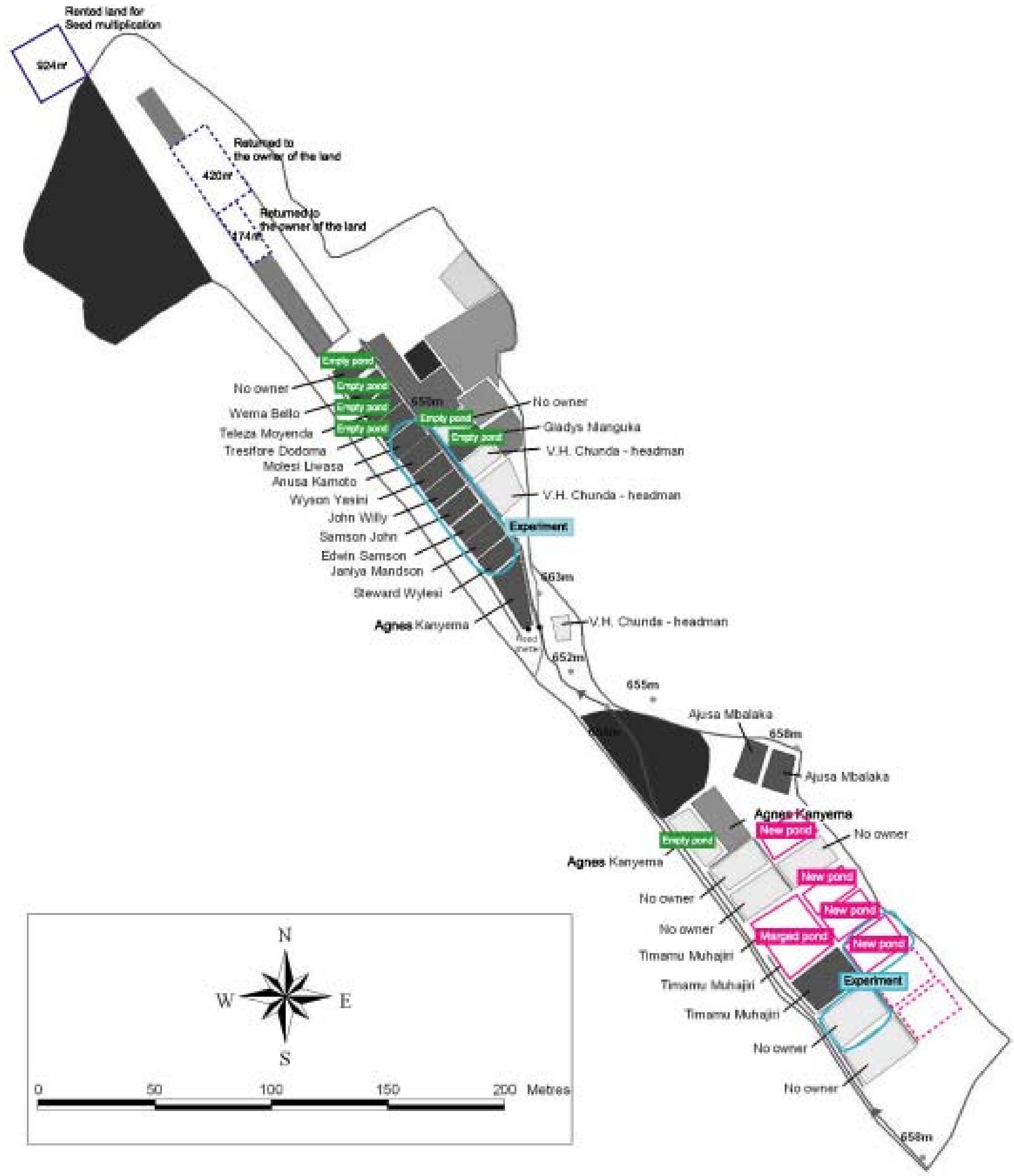
Attachment 14

Budget for Pilot Project Component 2

	Activities	Cost (US$)
(1)	**Identification of farmers' club**	**500**
(2)	**Training and visit**	**970**
(3)	**On-farm experiment**	**4,600**
(4)	**Copying best practice to new farmers' club**	**6,800**
(5)	**Evaluation**	**12,130**
	Monitoring and evaluation guideline	620
	Baseline survey	10,100
	Mid-term and final evaluation	1,410
TOTAL		**25,000**

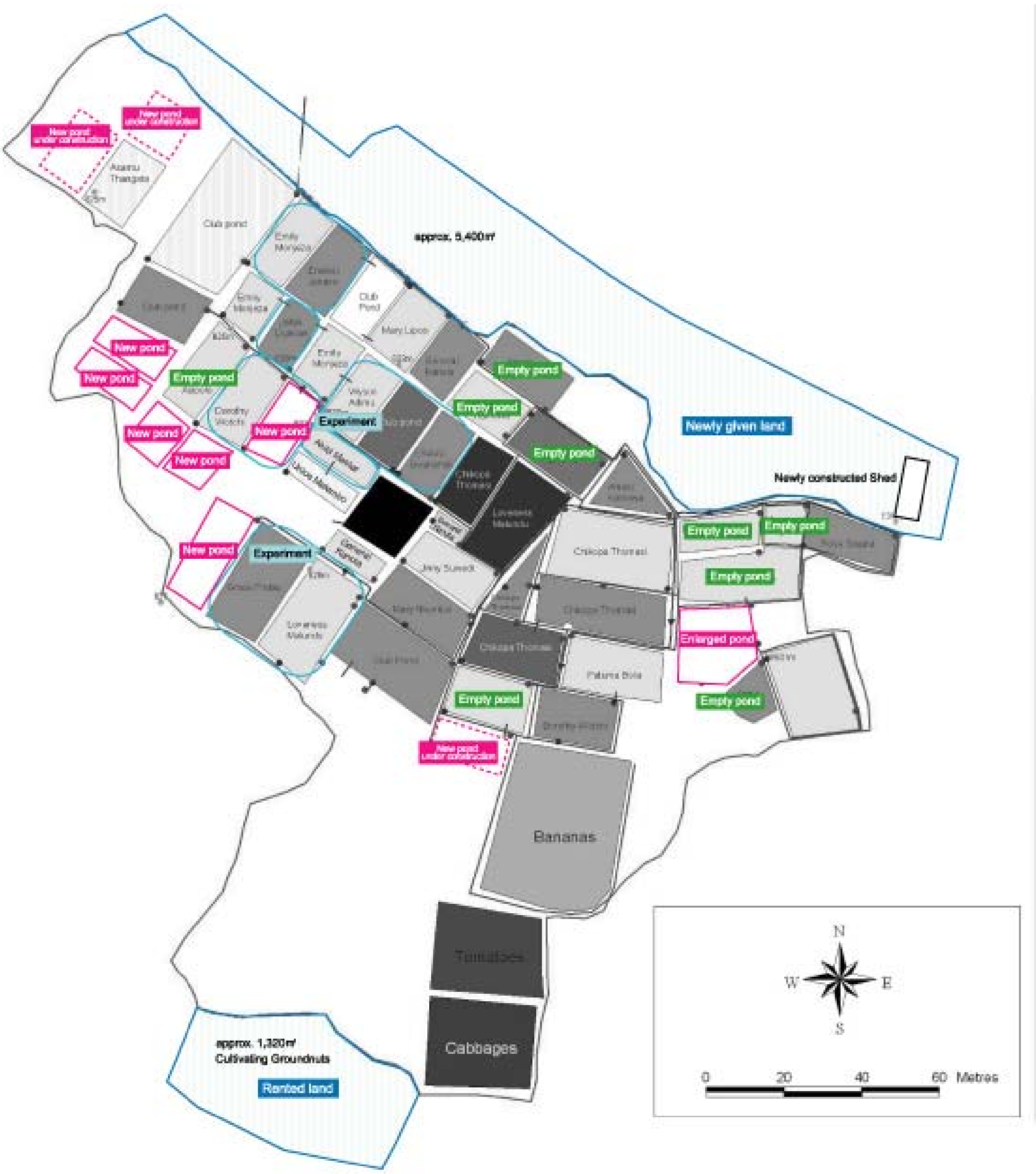
Attachment 15

Mawila farmers' club in February, 2005
(Changes observed after the Pilot Project implementation)



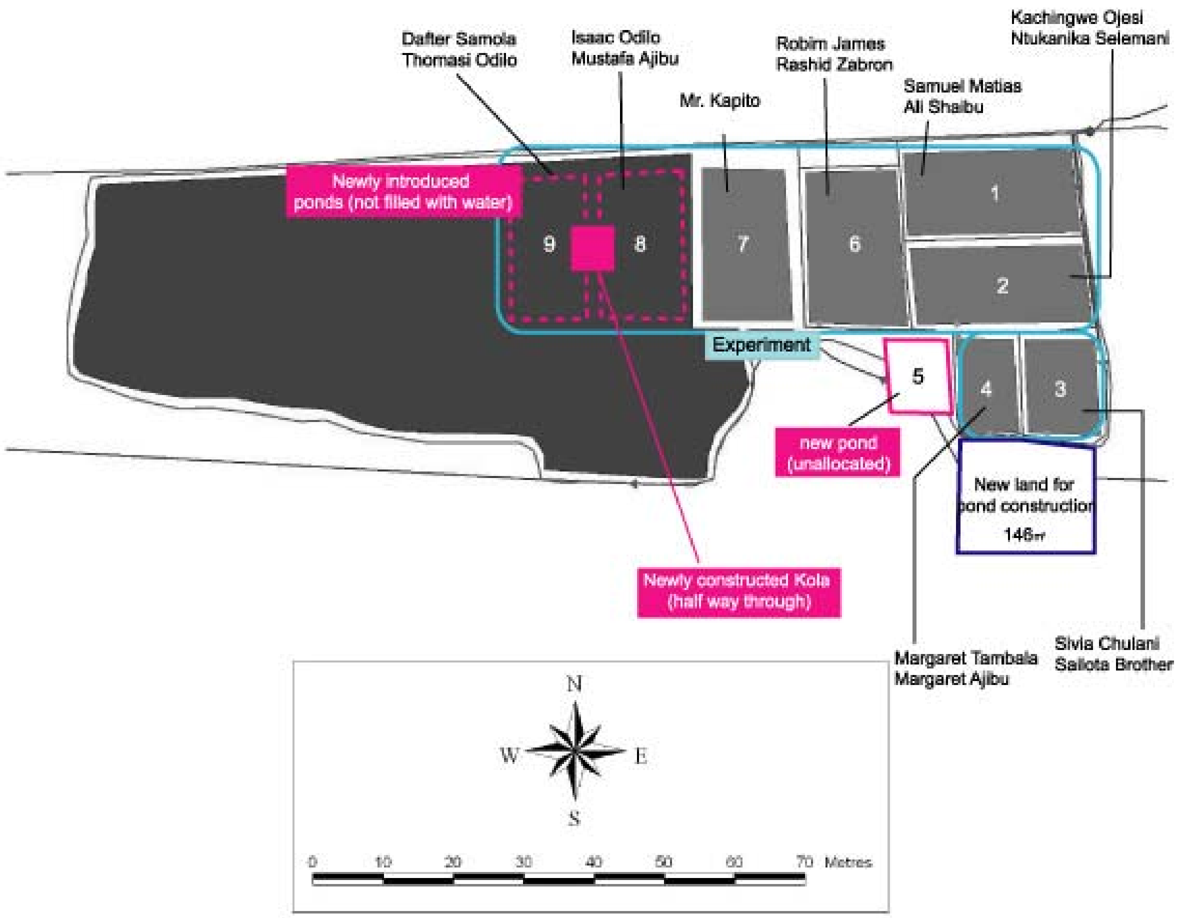
Attachment 16

Limbikani farmers' club in February, 2005
(Changes observed after the Pilot Project implementation)



Attachment 17

Mkamwalekani farmers' club in February, 2005
(Changes observed after the Pilot Project implementation)



Attachment 18

Farmers' Field school

<u>Steps for the Farmer Field School</u>

1. Sensitisation of the target farmer club, in this case, Mawila Farmer Club
2. Developing an action plan in participatory way
3. Construction of simple accommodation and a lecture room within the Club land
4. Training for farmer trainers (5 members of Mawila Farmer Club, Development Facilitator from WVM, innovative farmers in the vicinity area, the government extensionists)

   The table below shows possible training subjects for farmer trainers. Training can be implemented at Bunda college for a week intensively with some field visits.

Possible training subjects for farmer trainers

Contents	Trainer
Basic aquaculture technology	Bunda college/ NAC/ WorldFish Centre
Integrated agriculture technology	Ministry of Agriculture, Irrigation and Food Security (MAIFS)/ Bunda college
Basic business management/ farm management	Bunda college/ MAIFS/ Private sector
Extension methodologies	Department of Extension, MAIFS
Participatory approach (e.g. PRA)/ Community Driven Development (CDD)	NGOs

5. Selection of the target farmers within the District
6. Implementation of the farmer field school

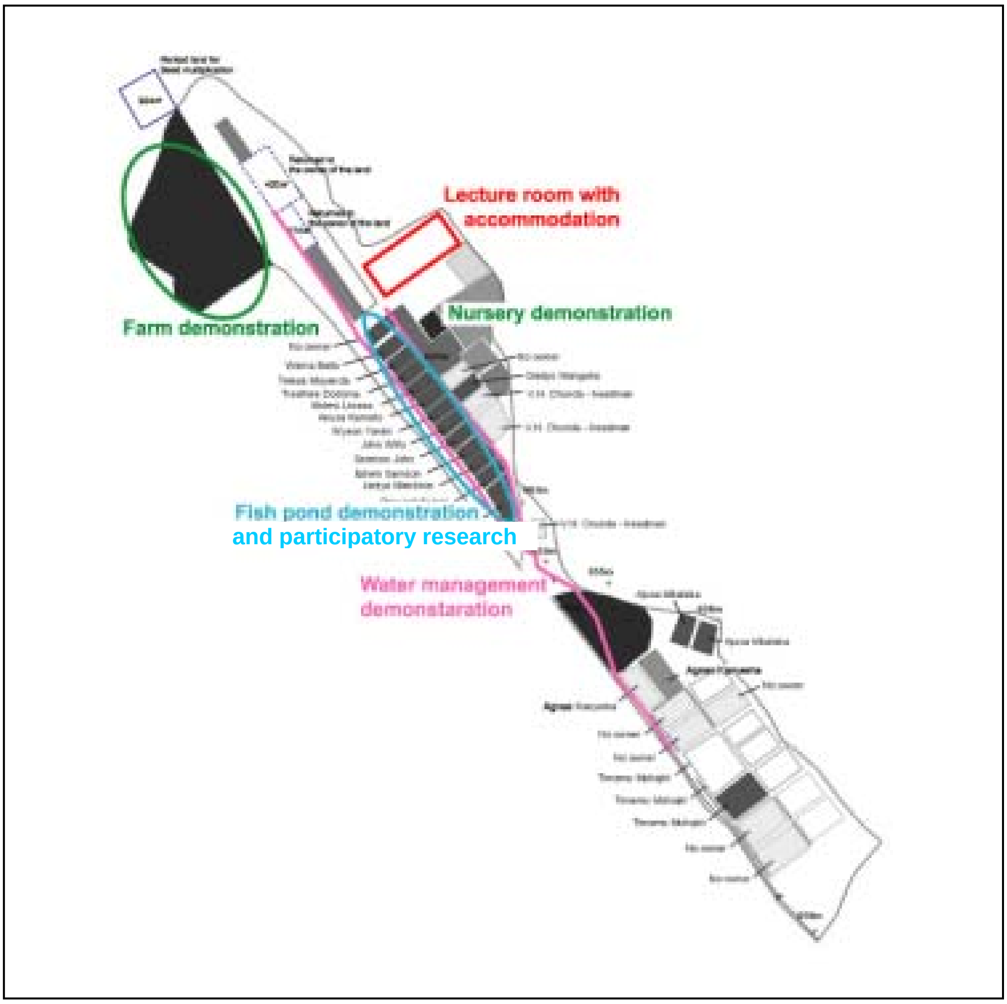
   The farmer field school will target approximately 20 farmers for 3 full days during dry season and 1 and half day during wet season. The reason of having a shorter period during the wet season is not to burden farmer trainers' own activities too much. For the same reason, three groups are the maximum to be targeted for a year for at least first several years, and utilise local extension staff and NGO as invited trainer.

   The proposed curriculum for the framer field school is shown in the table below.

The proposed curriculum for the farmer field school

Time schedule		**Contents**	**Trainer**
DAY 1 (dry season)	AM	The purpose of farmer field school	Mawila Club
		Discuss on expected output of the school	Participants
	PM	Visit sites and learn about dry season farming, water management, and pond management	Mawila Club
DAY2 (dry season)	AM	Technical know-how on dry season farming, water management, and pond management	Invited trainer
	PM	Record keeping and business management	Invited trainer
DAY3 (dry season)	AM	Develop their own farm design	Participants
	PM	Discuss with what they have designed	Participants
DAY 4 (wet season)	AM	Discuss on any adaptation of what they have learnt from previous session	Participants
		Visit sites and learn about wet season farming, water management, and pond management	Mawila Club
	PM	Technical know-how on wet season farming, water management, and pond management	Invited trainer
DAY 5 (wet season)	AM	Discuss on the output from the school Way forward	Mawila Club Participants

Below figure is to show how Mawila Farmer Club can act as a campus for the farmer field school.



Mawila Farmer Club with concept of the farmer field school

When the farmer field school is implemented, following challenges need to be considered.

1. High cost per trained farmer
2. The funding is required for a significant farmer outreach
3. Area specificity

Financial sustainability therefore needs to be fully thought through.

ADiM Working Paper 6

Commercial Aquaculture Development
-Its Potential and Risk-

Prepared by

Ibrahim Allahpichay
System Science Consultants Inc., Tokyo Japan

Commercial Aquaculture Development
-Its Potential and Risk-

Contents

Attachment

I. COMMERCIAL AQUACULTURE DEVELOPMENT

1. Background

1.1 Objective and Rationale

The objective of this study is to review the potential in terms of technical and non-technical aspects and the risks associated in pursuit to develop profit and market oriented commercial aquaculture. Aquaculture development is still in its infant stage and it is essentially urgent that the commercial aquaculture be promoted and developed for the following rationale or reasoning:

- To supplement the fish supply in view of the declining fish production from capture fisheries;
- To inspire and develop the present aquaculture practices whose efforts are mainly concentrated on small-scale, to a commercial level or more profit-oriented;
- To translate its past efforts in research and technology in small-scale aquaculture to a commercial level;
- To diffuse the knowledge from commercial aquaculture farms to rural aquaculture farms through on-site training, technology transfer; and
- to put into effective use of its water resources;

1.2 Study Methodology

The study period was about three months (February 01 - April 27, 2004) in Malawi; during which period a two-week trip was made to Zambia. The methodology included: collection and review of data/information, past reports, statistics; visits to aquaculture farms; interviews of fisheries officers and relevant government officers at headquarters and regional offices; interviews of relevant people in private sector (producers, feed manufacturers s, etc,).

In Zambia, the offices and farms visited are Chilanga Aquaculture Center in Lusaka, NARDC in Kitwe, aquaculture farms (in Kitwe, Macadamia Farm Ltd., Johnken Friendship Farm; near Lusaka, Kafue Fish Farm; in Chirundu, Chirundu Bream Farm; in Siavonga, Tune Enterprise, Trans-national Enterprise and Lake Safari, all conducting cage culture of Nile Tilapia); and two fish feed producers (Tiger Feed Ltd. and Amanita Feed Company).

2. Introduction

Aquaculture in Africa is insignificant in comparison to the rest of the world; the African continent has contributed slightly more than 400,000 tons, a mere 1.85 percent to the total world aquaculture production in 2001.

Aquaculture has been oriented to domestic markets and is mostly practiced by small-scale farmers. It has always been stressed that the African countries have tremendous potential for inland fisheries and aquaculture development and it is expected to play an important role in future by providing food and employment for people in Africa.

Aquaculture has been highlighted and emphasized on many occasions by policy-makers and development agents as an important initiative for Africa's economic development. For example; to emphasis the importance of aquaculture in Africa's economic development there has been a number workshops, technical consultations and meetings among the countries such as indicated below.

- Fourth Session of the Committee for Inland Fisheries of Africa (CIFA) (two decades ago in

Blantyre, Malawi)

- Africa Regional Aquaculture Review (1999, Accra, Ghana)
- Eleventh Session of CIFA (2000, Abuja, Nigeria)
- Twenty fourth Session of the Committee on Fisheries (COFI) (2001, Rome, Italy)
- Technical Consultation on Legal Frameworks and Economic Policy Instruments for Sustainable Commercial Aquaculture in Africa South of the Sahara (2001, Tanzania)
- Workshop on the Promotion of Sustainable Commercial Aquaculture in Zambia and Malawi (October 2002, Lusaka, Zambia)

As recent as in October 2002 “a workshop on the promotion of sustainable commercial aquaculture in Zambia and Malawi” has recognized and underscored the potential and a catalytic role aquaculture can play in food security, hunger reduction and poverty alleviation. The workshop had examined issues related to commercial aquaculture, identified the causes of the slow development and proposed possible strategies to ensure its successful expansion. The Workshop noted

- Great potential for commercial aquaculture
- Need to tackle the issue of feed, seed and access to capital
- Need to remind farmers to conduct aquaculture as a private business activity (where role the public sector needs to be clarified and kept at the very minimum).
- Need for collaboration between the public and private sector involved in commercial aquaculture in identifying positive and negative experiences in commercial aquaculture
- Policy to allow small-scale and commercial aquaculture to co-exist

The participants noted, among others, the following main constraints as always identified in African countries.

- A serious shortage of good quality fingerlings and feed
- Most aquaculture development projects implemented have targeted small-scale and emergent fish farmers and neglecting commercial fish farmers
- Extension and research agents are in most cases not conversant with complex production systems often imported by commercial fish farmers thereby providing little or no help to these farmers
- Commercial fish farmers lack an official forum for exchanging information and sharing experiences and the lack of national database on aquaculture which makes planning in aquaculture difficult.
- Lack of aquaculture investment policy
- Lack of specific credit facilities for aquaculture enterprises
- Very high interest rates (35-40 percent)

In context with Malawi, the major constraints to development identified especially for Malawi were species choice; availability and high cost of fish feed; limited modern technology; inadequate collaboration among donors supporting aquaculture; inadequate policy direction on specific issues and lack of appreciation by policy-makers of the ability of aquaculture to contribute significantly to the economy.

One of the major impediments to the development of sustainable commercial aquaculture that was focused in the workshop and that need immediate mitigating strategies is the difficulty of entrepreneurs gaining access to capital. Like in the rest of sub-Saharan countries, the problem in Malawi stems from lack of adequate collateral; prohibitively high interest rates being charged for loans; bankers’ perceptions that commercial aquaculture carries high risk of failure; lack of knowledge, on the part of farmers, of the modalities of approaching financial institutions for a loan; and limited knowledge, on the part of lenders, of commercially successful aquaculture enterprises.

The workshop noted that enabling policies should be in place for the promotion of sustainable commercial aquaculture, the workshop participants had stressed the requirement of sound enabling government policies for commercial aquaculture to take off and/or develop; with the following suggestions (that FAO could provide assistance in promoting commercial aquaculture in Zambia and Malawi.

- Capacity building
- Training in aquaculture management
- Transfer of technology through demonstration projects
- Institutional strengthening
- Defining aquaculture development zones
- Develop clear investment policies including investment incentives
- Tackle the problem of high interest rates (preferential rates in aquaculture)

In addition to above, legal framework conducive to promote aquaculture should be in place with aquaculture law that provides a secure right to conduct aquaculture operations, to the property on which the fish farm will be located, to water of the necessary quality and to the produce, and that the law also should establish control over the business through a permit or license system that ensure the environmental sustainability of aquaculture by examining the suitability of the proposed location of fish farms and potential environmental effects of the operations, subject the aquaculture operation to an EIA; supervision control over the use of exotic fish species, modern technology (including genetically modified organisms), and to any water quality concerns.

The workshop recognized that in spite of much unrealized potential for economically viable and sustainable commercial aquaculture in Zambia and Malawi, it is developing at a very slow pace and there is a growing interest that needs support. The recommendations, among others, addressed to Zambia and Malawi are: to speed up the preparation of clear national policies, strategies, plans and legal, regulatory and institutional frameworks with full participation of all stakeholders (feed manufacturing, hatcheries, processing and marketing, etc.); to support start-up aquaculture and related industries (such as private hatcheries and feed mills in their pilot stage with clear and simple regulations as well as fiscal incentives (tax exemptions, tax holidays, exemptions of import duty on machinery, and other inputs; to facilitate the establishment of models of economic and financial feasibility of commercial aquaculture ventures (these models would allow financial institutions to evaluate objectively investment proposals in aquaculture); to facilitate access to loans for commercial operators; to promote and support research and preservation of indigenous species; to strengthen the research-extension farmer linkages to ensure a proper and effective dissemination if research findings; to designate Aquaculture Development Zones with fast track mechanisms in place for investors.

The recommendations to FAO to assist are to urgently document and disseminate the sources of financing and existing funding mechanisms; to assist in the establishment or strengthening of commercial fish farmers' associations, lobby force and linkages of existing regional networks of commercial fish farmers; to create awareness among NGOs, donors, funding institutions and investors on the role aquaculture in supporting economic growth; to assist in the establishment of national aquaculture technical information resource centres (will provide fee-for-service extension/technical support and information); to regularly monitor, review and analyze the operational status of commercial aquaculture in Africa and disseminate success stories of aquaculture investment including policy development and implementation, and financial and economic successes and failures; and to assist the government to work on the necessary attributes for Zambia and Malawi to be able to export aquaculture products to the EU.

3. Development of Aquaculture in Malawi

3.1 Definition of Commercial Aquaculture

When is Aquaculture Commercial? It can be rather difficult when one categorizes fish farms and fish farmers according to relative sizes, degree of capitalization and profit motivation. The Committee for Inland Fisheries of Africa, CIFA (2000) defines commercial aquaculture as the rearing of aquatic organisms with the goal of maximizing profit (profit-oriented), where profits are revenues minus costs. Such operations may in fact not be profitable in the short run, but their behaviour is determined by the profit-maximizing goal, if unprofitable they will minimize losses. A commercial aquaculture producer can be small medium or large-scale, and is active participant in the market; he purchases inputs (including capital and labour) and engage in off-farm sales of the fish produced. Aquaculture, for him/her, is a principal economic activity.

Commercial aquaculture is done mainly by the private sector and without direct financial assistance from donor or government sources.

The prime objective of commercial operation is to grow fish for maximum profit, in contrast non-commercial aquaculture operation in which the producer may also purchase inputs, mainly seed and feed but relies chiefly on family labour and on-farm sales of the produce. Aquaculture could be one of the activities comprising the farming system undertaken to diversify production, improve resources use and reduce risk in the event of crop or market failure.

Therefore, a fish farm is not classified as commercial merely because it sells fish (it should maximize profit, be business-oriented and use hired labor). Commercial fish farming can emerge along a continuum from subsistence operations to genuinely commercial farms

Whereas, rural aquaculture as observed in Malawi, in which most of the output or harvest is consumed by the producer and his or her family, can be defined as carried out by small-scale farming or farmer household or communities; uses production technology appropriate for the area and the species; does not result in additional pressure on local resources; and helps to alleviate poverty. Commercial aquaculture is not an alternative to rural development, but rather a complement.

3.2 Present Situation of Commercial Aquaculture

Malawi, in reality has no commercial aquaculture activity, although it has been yearning for a commercial aquaculture venture while the same was sprouting in the neighbouring countries. Malawi can never claim or be proud to say it has a commercial aquaculture, while its policy clearly desires to establish and develop large-scale fish farming. In spite of a number of symposiums and workshops and technical consultations encouraging aquaculture development in the sub-Saharan African countries, aquaculture has not developed to the status or condition observed in Asia.

Malawi started to develop aquaculture technologies through research and development. Major efforts were made in the late 1980s; the policy then emphasized on the development and transfer of technologies appropriate for small-scale aquaculture. Most donors supported research and development but targeted the small-scale fish farmers who are considered the poorest of the poor in the society.

On the other hand, while the government was assisting and developing the small-scale fish farmers, the private sector began fish farming initiatives in sugarcane and tea estates and plantation since 1978 (FD classified them as commercial aquaculture), and several studies have been undertaken on the viability of commercial fish farming in Malawi (Balarin & Hecht 1991, Brooks 1992, Balarin 1997). The conclusion reached by Balarin & Hecht (1991) was that the price of fish at that time was too low for commercial aquaculture to be a viable proposition in addition to the technical and non-technical constraints facing aquaculture.

The most recent commercial trials is by Maldeco Fisheries on cage culture of Chambo, *O. karongae*. This initiative should be strongly supported as its success and failure could provide lessons for further expansion of commercial aquaculture. It also has important implications for the “Save the Chambo” campaign of the Department of Fisheries.

Some previous efforts to develop commercial aquaculture in Malawi are outlined below. Aquaculture activities by the private sector were on estates specialized in commercial crop cultivation (sugar cane plantation, tea estates). These estates began aquaculture because they had the resources, (pre-existing physical infrastructure of roads, irrigation as well as to their ability to borrow or use heavy, mechanized earth moving equipment from the estate) namely land, water supply, machinery, infrastructure. Their main objective was to provide fish to their workers, and to recruit labour force. These estate farms were stocked with fingerlings of selected indigenous species purchased from the national aquaculture stations.

(1) SUCOMA farm (Sugar Corporation of Malawi)

SUCOMA fish farm is located on a sugar estate near Nchalo in Chikwawa district in the Southern Region. The farm covers about 17.2 ha consisting of 28 ponds ranging in size from 0.1 to 1.0 ha. It was supposedly the largest commercial farm; the species farmed are *O. mossambicus*, *T. rendalli, Clarius gariepinus*, and including *Cyprinus carpio* with special permission from the Fisheries Department and average productivity ranged 3.1 to 3.6 tons/ha/year. The farm used to produce substantial quantity of fish from aquaculture and operated at a profit because most of the inputs into fish farm were re-circulated from factory wastes such as molasses. The SUCOMA fish farm, despite its low production was one of the most successful producing around 49 tons from 17 hectares. However, fish produced was not available to the general public as it was used to feed plantation workers on the sugar estate. The estate saved on production costs and improved profit by feeding the workers on the farm.

Currently, the farm operating at minimal activity only stocking fingerlings of common carp purchased from Kasinthula; this may stop as Kasinthula station has been leased to a private fish farmer. Also an interview with the farm manager indicated the estimated revenue (market value of fish produced) did not even break with the production cost due to lack of proper pond management practices, low stocking, high cost of labour; and in addition the new ILLOVO management is not serious about continuing the aquaculture activity.

(2) Dwangwa Sugar Estate Fish Farm

This estate fish farm was located in the Nkhotakota District in the Central region and covered about 3.2 ha. The produced around 94 tons in 1990 in both normal and sewage ponds, and the fish were produced the feeding of crocodiles whose skins were exported abroad. Fish produced was not available for the consumption to the general public. However, high value export product (crocodile skins) was produced from the fish. The Dwangwa Sugar Company has stopped aquaculture operation and a private individual other than the sugar estate was operating running the farm. At the time my visit the farm has closed down.

(3) Liwonde fish farm (Nu-Line Foods Fish Farm)

The farm located at Liwonde near the bridge, next to the Hippo View Lodge in the Southern Region. The total area developed was more than 10 hectares, with a concrete catfish hatchery. They had plans to develop further the farm to produce fish for sale in schools and other institutions of higher learning. The farm has closed down and the ponds are lying idle and derelict, and there was no sign of any hatchery facility.

(4) Benthos fish farm

This farm was established near Club Makokola in Mangochi. The farm had integrated ducks and horticulture farming and used to sell fish to the general public on daily basis at the farm gate, but has now closed down.

The Fisheries Department has categorized these estate farms as commercial farms; however, in real sense their operations did not resemble a business-oriented activity to make profit as well as to improve technical ability to produce efficiently. The fundamental reason is the priority of these farms was not fish farming; there was no interest to introduce technically skilled management. Therefore, these estate ponds did not progress to achieve to be a commercial-oriented enterprise, and most of them have been stopped aquaculture operation and closed down, and had no intention from the beginning to improve technical ability to produce efficiently.

The contribution by these "commercial" farms to the total aquaculture production figures remains small. Of the estimated 490 tons produced in 2000 only 120 tons was produced by the commercial sector (NAC 2001) at Kasinthula and SUCOMA.

The reasons for failure are many and include the lack of commercial fish farming expertise, inadequate fingerling production (quality and quantity), problems relating to the importation of inputs and equipment, infrastructural problems, lack of adequately equipped feed mills or expertise in feed mills to produce quality fish pellets, and fish farming not being the core business of the entrepreneur. Most importantly perhaps is the failure of Government fish farming stations to produce reasonable quantities of fish, which has sent the signal to business that fish farming is commercially non viable. The end effect is investor hesitancy.

A golden opportunity was lost; these estate ponds and aquaculture practices in the estates could have been developed and guided to a commercial entity if the government had encouraged and provided appropriate technical assistance.

3.3 Government's Effort to Develop Commercial Fish Farm

The government, in its effort to demonstrate commercial viability of fish farming, established a model commercial fish farm in 1969 as a component of the Shire valley Agricultural Development Project that was funded by the FAO/UNDP. The fish farm was allocated 30ha; out of the 30 ha, the Fisheries Department constructed ponds on 24 ha. The total number of ponds is 25 with the following areas: 9 x 300 m2 and 3 x 1,000 m2 for breeding fish and 1 x 3.5 ha, 10 x 1 ha and 2 x 6 ha for growing fish to table size.

During the project time, indigenous tilapias and catfishes were screened for suitability in aquaculture. Exotic species of Chinese carps and common carp were introduced in Malawi. The Kasinthula station at its peak supposedly had produced up to 98 tons of fish a year, and it was known to have produced tilapias in the range of 8-10 tons per hectare through semi-intensive farming system. Since the project was phased out in 1977, its activities on research and development and supply of fingerlings to interested fish farmers continued on a slower phase due to low government funding and lack of proper policies for promotion of commercial aquaculture. In the end the station did not emerge as a demonstration or model farm to attract investors. It was commented during the regional workshop (at Mangochi on August 3-6, 2004) that the station was earning substantial revenue from its sales of fingerlings and fish; however, the government did not allocate adequate budget for operation and maintenance. Likewise, another opportunity to develop and sustain commercial aquaculture was lost.

3.4 Policy and Legal Framework for Commercial Aquaculture

(1) Fisheries Policy

The National Fisheries and Aquaculture Policy 2002 of the Department of Fisheries has a principal goal for fish farming to increase and sustain fish production from smallholder and large fish farming operation (it infers to commercial aquaculture); the policy proposes a three-specific objective for fish farming development and associated strategies to achieve the objectives. The objectives and strategies are outlined below.

Objective 1: To solve problems related to fish farming and the management of small water bodies through biotechnical research.

Strategies:

- Recommend suitable management strategies for achieving optimum fish growth and fish production at different production intensities.
- Recommend brood stock and hatchery management strategies.
- Develop protocols for the management and conservation of the genetic diversity of farmed fish.
- Improve existing species through genetic selection, in breeding and cross breeding.
- Establish collaboration between aquaculture and capture fisheries extension and research to exchange information and experiences.
- Develop protocols to integrate fish farming into agriculture.

Objective 2: To develop adaptive/appropriate recommendations for fish farming

Strategies:

- Identify indigenous species for different climatic as well as agro-ecological zones for different scale of operations through on-farm research.
- Prepare economic analysis for different scales of fish farming enterprises and advise farmers accordingly.
- Assess productivity of reservoirs and small water bodies and test stock enhancement, management and utilization.
- Investigate socio-economic feasibility of the management of reservoirs and small water bodies.

Objective 3: To encourage farmers to adopt fish farming as source of subsistence and income

Strategies:

- Create awareness about potential of and encourage fish farming.
- Establish demonstration farms for integrated fish farming.
- Cooperate with agricultural extension officers to broaden knowledge about target group behaviour.
- Introduce and support participatory extension.
- Monitor and evaluate fish farming extension regularly to analyze limitations and constraints in fish farming practice.
- Cooperate closely and regularly with research projects and programme on fish farming and exchange findings.

An analysis of the policy and relevant comments are provided in Section of 4.3.1 of the Interim Report (November 2003). From the perspective of commercial fish farming, the policy needs additional objectives for institutional and manpower capacity building and a clear goal and objective for the NAC and other field stations. It is also imperative that the policies incorporate strategies for enabling policies at the overall level to include appropriate legal and regulatory and administrative frameworks and encouraging pioneer associations, and at the farm level to promote commercial aquaculture policies that could attract foreign investment, influence availability or provide start-up funding. In addition, it is also important the policy include strategies for the dissemination of on-station R & D regularly and effectively to smallholders and prospective investors for commercialization of aquaculture, and to conduct joint-collaborate aquaculture research or on-farm trials with private fish farmers.

(2) Fisheries Conservation and Management Act

The Fisheries Conservation and Management Act (No. 25 of 1997), passed in 1997, deals primarily with capture fisheries and contain excellent background provisions for administration, community involvement and enforcement that are equally useful in the long term in aquaculture regulation. Part VIII of the Act contains some useful building blocks for a modern aquaculture law, but it provides no more than the very first stage of the legislation that is necessary to encourage the development of sustainable commercial aquaculture.

The Fisheries Act contains four essential elements relating to aquaculture. It states the principle that no person shall set up or operate an aquaculture establishment without a permit and without a water right issued under the Water Resources Act. It grants the Director of Fisheries wide powers to impose conditions where an aquaculture permit is granted. It contains useful prohibitions against the transfer of fish, the introduction of non-indigenous species and the stocking of water with fish unless a permit is first obtained, and it enables the Minister, on the recommendation of the Fisheries Advisory Board, to make regulations for a variety of purposes, including the promotion and control of the cultivation of fish and the issue by the Director of a Code of Practice for the maintenance and operation of aquaculture establishments.

The provisions of the Fisheries Act are important, because they allow the government to establish its authority over the aquaculture industry and to exercise a measure of regulatory control through the power to impose conditions in a permit. Section 20 of the Act establishes that a permit is required in order to operate an aquaculture establishment and that any necessary water right must be obtained under the Water Resources Act (No. 15 of 1969). The section is specifically stated to apply only to such aquaculture establishments as are prescribed by the Minister in the official Gazette. Indeed, the provision in Section 20 (1)(b) of the Fisheries Act that the operator must acquire a water right is also inoperable until an establishment is prescribed in the Gazette.

Section 21 of the Act establishes the criteria for granting Aquaculture permits, and the criteria are: (1) an application for an aquaculture permit shall be made to the Director in the prescribed form and shall be accompanied by the prescribed fees; and (2) An aquaculture permit shall (a) not be transferred without the prior written consent of the Director; (b) confer on the permit holder exclusive rights to harvest the products of the aquaculture establishment within the area specified in the permit; (c) be subject to such conditions as appear to the Director to be necessary or expedient for the regulation of aquaculture, the management of fisheries or the economic benefit of Malawi and, without prejudice to the generality of the foregoing, may conditions relating to – (i) the siting, design and materials used in the construction of aquaculture establishment; (ii) sanitary conditions of fish and fish products; (iii) measures for the prevention of the escape of fish farmed for aquaculture; (iv) measures for the prevention of fish diseases; (v) the marketing of fish and fish products of the aquaculture establishment; and (vi) measures to be taken to minimize the escape of waste products and the pollution of land and water.

(3) Environmental Act and EIA System

Environment Management Act of 1996 (Act 23 of 1996): provides an adequate basis for ensuring that proper environmental controls are imposed on aquaculture operations. Those who wish to discharge effluent into public waters must apply for a ministerial consent, though this provision appears to be aimed at a planned source of water pollution, such as a sewage plant, rather than to the unintended pollution that might be produced by a fish farm. The Fisheries Act also contains a prohibition against disturbing or injuring fish by any one of a list of activities, though none of the listed activities relate directly to water problems that might be produced by aquaculture.

The main protection against pollution resulting from future commercial aquaculture operations is found in the Act. This Act also makes it an offence to discharge or emit a pollutant into the environment and could apply to any pollution resulting from aquaculture that was not directly covered by the Fisheries Act. However, the main importance of the Act in relation to aquaculture lies in its environmental assessment provisions.

The Act states that an EIA must be carried out in relation to all projects of the types and sizes listed in the official Gazette. The listed projects include: a pond fish farm with a capacity of more than 100 cubic meters; a pond fish farm which will result in a direct discharge into a receiving water body; any proposal to introduce species into an area where they presently do not exist.

The EIA provisions offer some assurance that all future aquaculture projects of any significant size will be properly screened. However, the first two threshold tests seem unusually rigid. Many small fish farms may exceed 100 cubic meters in size, or may result in a minor discharge into a water body, but pose no significant threat to the environment. Yet under the legislation, they must undergo a potentially costly EIA.

These stringent provisions are intended to act as screening devices and that, after the submission of a project brief, the Director would determine whether an individual application would be required to undergo a full EIA. Under Section 24, proponents of all projects of the type and size listed in the Gazette must submit a brief and, under section 26 (3), no license can be issued for the project until it has been approved by the Minister. Once the Director has received a complete project brief, section 25 states that he shall require the developer to conduct an EIA.

Malawi thus certainly has in place effective procedures to screen the environmental acceptability of future aquaculture projects. However, those procedures may unintentionally subject some commercial projects to a full EIA, although they do not pose any significant environmental threat. This danger could be minimized if Section 25 were amended to enable the Director (or preferably the Aquaculture Agency) to waive the requirement of an EIA where the brief indicates that the project poses no significant threat to the environment. The Director/Agency's decision should be made public and subjected to an appeal by affected parties.

The “Guidelines for Environmental Impact Assessment, December 1997” provides the guidelines to regulate the EIA process. This guideline provides the types of projects for which an EIA may be required. A guideline on formulation of the EIA in Aquaculture is outlined Appendix-1.

<u>A case study in Zambia: Conflict between ECZ and Cage Culture Operators</u>

A conflict between Environment Council of Zambia (ECZ) and Aquaculture Operators (in Siavonga-Lake Kariba Using Floating Cage for culture of Nile Tilapia) is introduced here as lessons to be learned.

Aquaculture operations are subjected to the Environmental Protection and Pollution Control Act (No. 12 of 1990), which contains in Part IV adequate provisions for dealing with any water pollution that may result from the operations. The Environmental Impact Assessment Regulations made under that Act (1997, S.I. No. 28) set out the rules for when an environmental impact assessment is required for a proposed aquaculture project. The general rule is that a project brief is required for any fish farm which will have a production of more than 100 tons per year. A brief can also be required if the project will be located in or near an environmentally sensitive area, such as an area which supports rare or endangered species or a major water catchment area. If the brief indicates to the Environment Council of Zambia that the project is likely to have a significant impact on the environment, then the Council can require a full EIA.

The upper limit requirement for submitting a project brief means that most large-scale aquaculture proposal would be subjected to an EIA. However, most non-intensive smaller projects are free of that requirement, unless they are located in environmentally sensitive areas. The approach of defining the need for an EIA by the size of expected output from the project courageously prevents non-intensive small-scale proposals from incurring the unnecessary costs of submitting a project brief, but it does not guarantee that all potentially harmful projects will be screened. For example, a proposal for cage culture of exotic species in a lake would not be subjected to automatic screening unless its annual production exceeded 100 tons or unless the lake is classified as environmentally sensitive.

Therefore, four cage culture operators of Nile Tilapia, who had the approval of the Fisheries Department to conduct aquaculture operations, did no through the process of submitting project brief to ECZ for a EIA requirement as they are to understand that there is no need for a EIA and further FD did not advise them. Each operator's production output did not exceed 100 tons a year (in fact it was less than 30 tons a year). Late last year (2003) ECZ gave a notice with an ultimatum that their cage culture operations have to be terminated and dismantled unless they are subjected to EIA. With this ultimatum, a conflict arose between them and ECZ; and the Fisheries Department that issued the permit could not be of any assistance in solving the issue. Finally, it seems the entire cage culture facilities were dismantled and destroyed by ECZ.

The lesson learned here is that there is no proper channel of procedures and communication among relevant authorities (i.e. Environment Council of Zambia, Fisheries Department and local government). There was no system that could provide legal channels through which the operators could express themselves and solve the issue. There is a need for a single agency or a single window (that controls all aspects of aquaculture) as a facilitator for acquisition of the rights that are necessary in order to operate a fish farm. The aquaculture operators had become victims due to lack or absence of proper or enabling policies and regulations that would have guided them smoothly.

(4) FAO Code of Conduct of Responsible Fisheries

FAO Governing Bodies recommended and formulated a global Code of Conduct for Responsible Fisheries that would establish principles and standards applicable to the conservation, management and development of all fisheries. The Code was unanimously adopted on 31 October 1995, provides a necessary framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment. The Code is voluntary and is global in scope, and it sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity.

The FAO Code of Conduct for Responsible Fisheries, under Article 9, urges responsible aquaculture development. Therefore, national and regional implementation of the FAO Code, the Convention on Biological Diversity and other existing laws and policies, must be pursued in a manner which ensures that unsustainable aquaculture is prohibited, before there is more irreversible damage, loss of biodiversity, or harm to communities.

The Article 9 of the Code refers specially to aquaculture development (including culture-based fisheries) with four sub-articles, namely responsible development of aquaculture under national jurisdiction; responsible development within transboundry aquatic ecosystems; use of aquatic genetic resources; and responsible aquaculture at the production level.

The necessity for aquaculture to develop in a responsible manner is supposedly generally well accepted and understood in government and academic circles in member countries, that is including Malawi. Aquaculture on a commercial oriented approach is relatively a new concept in Malawi; therefore precautionary approach and code of practices have to be incorporated in commercial aquaculture. It is perceived that awareness of the concept of responsibility has to be instilled among owners and operators of large-scale and intensive farms. However, small-scale and traditional fish farmers would generally be ignorant of the concept, and some resistance would be expected due to higher costs.

The concept of code of responsible aquaculture has not been adequately incorporated in the current legislation, regulations and policies, although there is generally a positive attitude and recognition of the concept within the relevant authorities. Therefore, special provision are taken by the public sector to make aquaculture producers and suppliers aware of the potential risks and irreversible adverse changes that may occur if the concept of code of practices for responsible aquaculture and sustainable resource use is made to be recognized by the public and the concerned. Refer appendix-2 for detail provisions (Article 9) on the Aquaculture Development.

(5) Investment Law and Relevant Regulation

Malawi has adopted a position which encourages investment in aquaculture projects and there are no particular restrictions on aquaculture investment. Indeed, the publications of the Malawi Investment Promotion Agency highlight investment in aquaculture and the Cabinet is reported to have approved the removal of duties on imported equipment. This change will place aquaculture on the same commercial footing as agriculture. A ministerial committee is reported to use an informal single window approach to the approval of foreign investment applications.

4. Opportunity and Limiting Factors of Commercial Aquaculture

An analysis of the strengths and limiting factors (weakness) or problem areas that are critical to aquaculture development was addressed that can prompt actions and responses in order to recommend an effective strategic planning.

4.1 Factors Limiting the Development (Emergence) of Commercial Aquaculture

What are the factors and situation limiting the development of commercial aquaculture and not encouraging or attracting private investors to embark on commercial aquaculture? The prevailing situation with respect to technical and biological aspects in the sector is not conducive or attractive for prospective private investors to embark even on a small-scale profit-oriented aquaculture.

Some of the factors and situation (contentious and debatable) limiting the development of commercial aquaculture and not encouraging or attracting private investors to embark on commercial aquaculture are addressed below.

(1) The indigenous species suitable for culture have not shown that the species would be easily reproducible with low mortality and low feed conversion ratios on a commercial operation (economic viability), although substantial research and on-station trials have been conducted. Indigenous tilapia species: namely *Oreochromis niloticus*, *Oreochromis shiranus*, *Tilapia rendalli*, and *Oreochromis Karongae,* have not been adequately domesticated for commercial aquaculture.

(2) Absence of proven technology for commercial culture of indigenous fish species: The indigenous species, especially *O. karongae*, *O. shiranus* and *T. rendalli* have not shown good “commercial” performance, although considerable research and extension in small-scale aquaculture have been done for these species, but not for commercial aquaculture.

(3) Availability of seed (fry and fingerlings): Sufficient good quality seed (fry and fingerling) are also lacking in Malawi. Aquaculture stations are technically not producing seeds due to shortage of operational budget. A good example is the problem encountered by Maldeco Aquaculture Ltd. in its effort to collect brood stock and fingerlings of *O. karongae* for its cage culture. Technically, it can be said that the selected indigenous species have not been adequately domesticated to produce and supply quality fingerlings.

(4) Availability of quality feed at low cost: Feed normally accounts for more than half of the operating cost in most commercial operations. No fish feed making experience even on a small scale in Malawi. JICA Technical Cooperation had conducted formulated feed trails using local ingredients; supposedly it had low feed conversion ratio and the estimated feed cost was about Kw80 per kg. This price is relatively very high. In general, in most African countries there is limited demand for fish feed and high cost of agricultural by-products have handicapped the development of fish feed industry.

(5) Status of Existing Fish Farms: Existing fish farming are not model of commercial operation or have shown good track record. Most farms have terminated their operations or never progressed or developed to a sustainable business enterprise for various reasons. It should be noted that these farms never in the real sense embark on a commercial-oriented venture. These farms were merely started fish culture activities because it had the resources, such as water bodies or reservoirs, by-products of the estates, etc. in order to supply fish to their workers. Therefore, the limited development of the farms did not exhibit any vibrancy or attractiveness for other to embark on commercial aquaculture.

(6) Entrepreneurial motivation and managerial expertise is also lacking in Malawi. A case in point is the SUCOMA fish farm; with 17 ha of fish pond embarked on fish culture and it could never emerge to a commercial-oriented activity due to absence of dedicated farm personnel with aquaculture expertise. (Lack of entrepreneurial dedicated farm managers)

(7) Results and activities of research and development activities at National Aquaculture Center (Domasi) that could be referred to by prospective investors are not disseminated either through annual reports or other means. In other words, there is poor centralized information sharing or dissemination. Therefore, the impact of current research and development is not reflected in output as commercial aquaculture has been limited or none. Research is not oriented to demand-driven.

(8) There is no clear policy on the use of exotic fish species in aquaculture. At one time exotic fish species were introduced to promote aquaculture development; namely common carp exhibited very good growth performance, and later in 1991 it was banned in to conserve the biodiversity.

4.2 Prevailing Situations (Strengths and Opportunities) Conducive to Aquaculture Development.

What are the prevailing situations with respect to technical and biological aspects in the sector is conducive and attractive for prospective private investors to embark even on a small-scale profit-oriented aquaculture? They are:

<u>Strengths</u>

(1) The government has finally acknowledged the importance of aquaculture in the food security and poverty alleviation. So, in this context, it is expected that the government would adopt enabling aquaculture policies that would entice investors who are reluctant and hesitated to take up aquaculture.

(2) The aquaculture facilities include a national center (NAC) and two fish farming stations (Kasinthula and Mzuzu) and extension stations; all are strategically located and well equipped, including the regional research station of World Fish Center (Domasi). Considerable research and development works on breeding, fingerling production and grow-out on-station levels; these research and aquaculture techniques (are encouraging) know-how have not been adequately utilized in aquaculture commercial development.

(3) Past projects (GTZ/EU) have identified a potential indigenous candidate “Chambo” (*O. karongae*), which has low fecundity, late in maturing and also popular among Malawians, for fish farming development, especially for commercial sector. This fish Chambo has not been explored for commercial aquaculture.

(4) The on-going ADiM project (JICA) with various activities and pilot projects including technical training to stakeholders (fisheries officers and innovative fish farmers) is expected to strengthen the capability and ability and to inspire them to commercial aquaculture venture.

Opportunities

(1) Malawi has high potential for aquaculture as the country is endowed with suitable land and water, and relatively cheap labour, and cumulative technology know-how acquired from about 40 years of research and technology development with donors' technical assistance.

(2) There are four suitable indigenous fish species that are culturable but not adequately tried at commercial level, and are popularly accepted by consumers.

(3) There is a high demand for fish both in rural and urban area due to decline in landing of capture fishery; presently fish price is high, on average it is about US$1.80 to US$2.00/kg. Hence, there is an unsatisfied domestic demand for fish.

(4) There is tremendous opportunity for fish feed development. Local ingredients of cereal- and pulse-based are ingredients including by-products are available locally, such as soya beans, pigeon peas, peanuts, etc. In fact some of these are imported by processors/manufacturers of feed in neighbouring countries. Adequate efforts have been made in Malawi to source these materials for feed formulation.

(5) Government has realized the need for reforming and setting enabling aquaculture policies to involve more private sector role to promote commercial aquaculture. It has set up an aquaculture task body consisting of researchers, policy makers, and private commercial aquaculturists to trash out the issues/problems and formulates priority areas for development.

(6) Depending on the policy change on the use of exotic fish species in aquaculture, there are fish species with track record (fast growth and low feed conversion) in commercial aquaculture; another opportunity to consider.

Threats

There are threats that would hinder the promotion and development, though these threats could be overcome to some extent with the government cooperation in setting in place enabling policies and legal framework and encouraging environment that would inspire the private sector participation. The threats noted are:

(1) Government is heavily relying on external funding and it may hinder long-term development.

(2) Hesitancy of private sector to venture into commercial aquaculture on preconceived idea that risks are high.

(3) Lack/absence of experience in commercial aquaculture, including no entrepreneurial skill and expertise in large-scale fish farming.

(4) Slow and poor growth performance of local culturable fish species unless selective breeding, genetic improvement, etc. of the species.

(5) Adverse ecological impacts of escapees of exotic species, if introduced to Malawi for aquaculture use.

4.3 SWOT Analysis of Commercial Aquaculture

SWOT analysis with reference to identified strategic areas, namely, commercial aquaculture technology, choice of suitable indigenous fish species, inputs (seed and feed), market and use of exotic fish species are summarized below. From the analysis it is noted that promoting commercial aquaculture has a strong point in view of the availability of research experience and know-how technique that should be immediately put to viable use (to achieve profit oriented fish farming). The availability of local resources, especially ingredients for fish feed adds strength to the aquaculture development. The government is serious and willing to enact policies and set legal framework in order to promote large-scale fish farming. The weaknesses are expected to be gradually phased out with the implementation of the priority projects and recommendation that are being formulated in the on-going master plan study.

The introduction of an exotic fish species could be preferred by some policy makers as it is most sought after fish by entrepreneurs; but Malawi is signatory of international conventions and agreements, and it is legal obliged to adhere to international standards and principles. If DoF proposes to introduce an alien species, it should consider carefully as there will be international outcry and if it is still wants to use in aquaculture, Malawi should follow precautionary approach and implement a risk analysis strictly before making hasty decision.

1) Commercial Aquaculture Technology, 2) Choice of suitable native fish species, 3) Inputs (Seed and Feed), 4) Market/Demand, 5) Exotic fish species	
Strengths	Weakness
• Aquaculture is recognized as important to food security • DoF with strategically located aquaculture facilities (NAC); two farming stations (Mzuzu and Kasinthula); World Fish Center Research Facilities, and Bunda College (Aquaculture and Fisheries Dept.) • Considerable research on breeding & fingerling production has been conducted at on-station level. • Past projects (GTZ/EU) indicated O. karongae a candidate for commercial aquaculture. • Pilot projects (ADiM) are foreseen as an important contributor to the various activities that encompass a viable commercial aquaculture. • Field research and extension stations are strategically located. • Technical training imparted to farmers and DoF staff (ADiM) • Trained staff (research and extension) available • Desire to adopt enabling aquaculture policies.	• No long tradition of fish culture • R & D not tested at farm level for economic viability. • Limited research activity at field stations (insufficient budget) • Field stations could not supply needed fingerlings (limited financial means and/or neglect) • Lack of quality fry & fingerlings (inadequate research & limited budget) • Poor centralized information therefore lack of information sharing • No clear policy on the use of exotic fish species. • Prohibition on introduction or transfer of exotic fish species (Fisheries Act)
Opportunities	Threats
• Malawi endowed with land & water, relatively cheap labour. • Four indigenous species are culturable and have high demand • Natural and wild broodstocks available. • Local raw materials available (including by-products) • High fish price and demand • Existence of an unsatisfied domestic market for fish • Urban domestic market for farmed fish • Good performance (fast growth & low FCR) of exotic fish species • Adoption of enabling aquaculture policies. • Shift in the public sector's role in aquaculture development. • Encourage private sector's role in supply of inputs (seed and feed). • Introduce fish species with track record in commercial aquaculture (fast growth and high feed conversion)	• Relies heavily on external funding and it hinders long-term establishment • Poor management leading to low yield and not suited for commercial • Lack of managerial skill and expertise (for commercial aquaculture farm management • Slow and poor growth performance and not attractive to investors (unsuitable culture species or inbred stock) • No locally produced feed (no demand) • High feed cost (imported) • Investors are hesitant to venture due to (more unknowns than known in technical / biological pre-requisites) and inadequate enabling policies • Lack of private sector involvement, including insufficient supply of inputs by the private sector • Accidental escape or release of introduced exotic fish species, and may establish in natural environment. • Likely to become a pest; damaging to environment and the farming of other species • Ecological dangers from the import of exotic fish species (biodiversity of Lake Malawi needs protection conservation)

5. What Approach to Take for Commercial Aquaculture

5.1 Pre-requisites and Policy Considerations

Development of profit-oriented aquaculture either on a small-scale or large-scale is the purview of the private sector. While Malawi may have high development potential for aquaculture in view of the rich freshwater resource, high demand and high price of fish, but any prospective investor or emerging fish farmer would only embark or initiate aquaculture unless the investor is secure a quick return on investment. It is one of the external threats as pointed out in the SWOT analysis, i.e. prospective investors are hesitant to take up aquaculture due to (more unknowns than known in technical / biological pre-requisites) and inadequate enabling policies.

Therefore, it is understandable that before one takes an approach for commercial fish farming in Malawi, it is necessary to confirm that the prerequisites for successful commercial aquaculture or fish farming are in place, as it is the fundamental goal of any investor to make as much profit as possible from investment.

<u>Technical pre-requisites</u>

The prerequisites at the technical level are: the ability to produce at a low cost which is primarily determined by fish species, location and feed. The species selected should meet certain biological pre-requisites; that are the ability to cultivate a species from fry and harvest is not critical and easily reproducible with low mortality and low feed conversion ratios. Site selection is another critical factor that influences the profitability; the choice of location affects fixed costs such as construction, operating and distribution costs, and the topography where water is available regularly at suitable temperatures lower operating costs. Availability of quality feed and seed are also critical; feed accounts for more than half the operating costs in most commercial operations. In most African countries, limited demand for fish feed and high value of agricultural by-products have handicapped or hindered the development of fish feed industry (there are exceptions). Adequate good quality seeds are also lacking in many countries including Malawi.

<u>Non-technical pre-requisites</u>

As important as biological and technical feasibility is economic viability. There must be a demand for the product for aquaculture to develop; in addition to existing demand there should be the potential for increased demand in future. Other requirements are willing to take risks such as meteorological shocks (seasonal flooding, drought, etc.), political risks (government interference with business operation, uncertainty over property rights, weakening institutional factors), and social uncertainties; accessibility to financial resources (in addition to capital cost, for most commercial fish farming variable or operating are a major component of total costs, that can cause imbalance in cash flow). Entrepreneurial motivation and managerial expertise is also important because it requires perseverance and an ability to take risks.

<u>Policy and legal pre-requisites</u>

In addition to the above pre-requisites, which are outside the control of government and policy makers, there are conditions that have bearing on aquaculture development and can be influenced by the government; they are policy variables. Therefore, enabling policies which government can implement to promote the sector should be in place, and should be designed to reduce risk and lower costs for all business activities by creating a climate conducive to private emergent commercial fish farmers. In other word, these policies are "business-friendly" and are referred to as non-sector specific policies and sector specific policies. Non-sector specific policies are good governance, openness to trade and macro-economic growth and emphasis on private investment. On the other hand, sector-specific policies are specific to aquaculture and which are meant to guide the development of aquaculture sector. The policies are regulatory/legal, administrative and aquaculture laws/regulations that would provide an orderly and sustainable environment for development to reduce negative externalities such as pollution or conflicts over water rights, land rights, property rights, licenses, permits; introduction of alien species policies; privatization of hatchery and extension services; marketing policies, promotion of fish farmers associations, research and technical development policies, etc.

<u>Prevailing Situations</u>

Under the current situation in Malawi in terms of technical and non-technical pre-requisites, launching or start-up of commercial aquaculture is a serious and challenging issue in view of the absence of suitable proven technology for indigenous species coupled with slow growth performance and other factors that have kept investors away. There are more unknowns than known (refer constraints/issues described in Section 4.1.3 of Interim Report.

Aquaculture is still in its infancy in Malawi and it plays only a minor role in the country's economy. Despite the prevailing constraints in technical and non-technical aspects, there are two investors who have recently taken a bold approach to launch commercial aquaculture: Maldeco Aquaculture Ltd (a parastal company) has plan to grow-out local indigenous species known as "Chambo" (*Oreochromis karongae*) in floating cages in Lake Malawi, and it has begun to construct hatchery, breeding, nursery ponds and raceways. The other new investor is GK Aquafarms Ltd (a private fish farmer) has taken a lease of the Kasinthula Fisheries Station in Chikwawa (lower Shire) for commercial pond culture; the investor has begun clearing site and rehabilitating the ponds and plans to use indigenous tilapia species and common carp (*Cyprinus carpio*) for the time being. The bold approach and pioneering efforts of both is considered a research and development phase towards commercial aquaculture as they are willing to undertake the initiative as an "infant industry" on a species that has not been adequately domesticated.

5.2 Development Approach

With the two emerging fish farming ventures cited above, it does not pave the way for other prospective investors to embark or initiate aquaculture. As discussed above what is keeping away or not attractive to the prospective investors is absence of suitable proven technology for indigenous fish species, sound government policy including institutional and legal framework for aquaculture. There are investors willing to initiate aquaculture on a commercial scale if the use of an alien fish species that have shown good track record in terms of growth and marketability, is permitted.

Malawi, like in other African countries, is too under increase pressure to maximize food production, rapidly and cheaply due to growing poverty and population, and this includes for the fisheries sector too wherein the fish supply from capture fisheries is declining; the importance of aquaculture as a contributor to food security and poverty alleviation is emphasized. More emphasis is placed in the promotion of fish production from smallholder and large fish farming operation in line with stated objective and guiding principles in the National Fisheries and Aquaculture Policy (October 2001). Therefore, policy or decision makers trying feed hungry people and investors seeking quick returns are strongly compelled to use or introduce exotic fish species that have proven its worth in other countries. There are two schools of thoughts among the policy makers in Malawi that is indigenous species versus exotic species on the use in commercial aquaculture.

In view of this circumstance, two options are suggested for the promotion or emergence of commercial aquaculture. The first option is the use of only indigenous fish species and the other option is to consider the introduction of exotic (alien) fish species only after adequate risk analysis (assessment) is conducted.

(1) Option -1: Use of Only Indigenous Species

Given the past research that has been undertaken, it is clear that the most suitable indigenous species that have been identified for aquaculture in Malawi are cichlids *O. shiranus* and *O. karongae*, *T. rendalli* and an African catfish (*Clarias gariepinus*). These species currently are the mainstay of small holder fish farming. However, knowledge and information on high yield production technology of these species is still poor. Although substantial research and development at on-station level have been conducted, it has not been translated or tested on a farm level or commercial level to show technical and economic viability. Hence, if the government policy does not allow the use of exotic species in aquaculture, for example the commonly sought after fish species, namely common carp and Nile tilapia, research and development on commercial culture technology and operation and management need to be immediately carried out.

- Conduct on-farm operation of selected indigenous species (translate the on-station research and development that have been conducted so far at NAC and other field stations to commercial operation). This will ensure economic and financial viability.
- Conduct joint feasibility studies (joint on-farm research) with private sector (possibly with Maldeco Aquaculture and/or GK Aquafarms in Kasinthula) to verify and evaluate the technical data and information gained from on-station research trials and activities.
- To lessen the burden on fingerling production by the fisheries stations to reduce cost, encourage production of fingerlings from fry stage by small-scale fish farmers (technology transfer).
- To initiate and conduct immediately selective breeding and genetic improvement of indigenous fish species.

(2) Option – 2: Use of Exotic Species

Why would any prospective investor consider an exotic fish species? What species to be farmed is an important question among prospective investors, and it depends on three factors that guide the choice of species for commercial aquaculture: the market, technology and a species selection between a native (endemic) and an introduced (alien) species. Cultivable indigenous fish species are not good candidates among the investors, and if a commercial fish farm is to succeed, investors or fish farmers would always consider the use of an alien species in commercial aquaculture, namely common carp and Nile tilapia. Their keen interest stems from the successful commercial farming of introduced species, especially in Africa and Asia.

The introduction of exotic species in Malawi is banned by the Fisheries Conservation and Management Act 1997. They are well aware of the fact that exotic species particularly common carp and Nile tilapia have been introduced in the neighbouring countries and are being used successfully in commercial aquaculture. Common carps and Chinese carps (grass and silver carps) were introduced in Malawi the 1980s for aquaculture use, and later banned in 1991. A hybrid of tilapia (red tilapia) was brought into Malawi in 2002 from Malaysia; but it was confiscated and not allowed to be used in aquaculture.

Introducing an alien species is a two-edged sword; it can replenish fish supply or devastate a habitat or environment. Alien species are recognized as one of the most significant threats to natural aquatic ecosystems. Although introduction of alien species has usually resulted in ecosystem disruption everywhere it has been tried, these species are a valid means to improve production and economic benefit from aquaculture. A balance must be struck between the ecological dangers from introduction of alien species and potential benefits. Therefore, policy makers must weigh the costs and benefits in their decision whether to introduce a new species or review on the use of common carp (an introduced species in Malawi) after giving due attention to a thorough and proper risk assessment according to recommended rules.

Why indigenous species should be encouraged or promoted in Malawi? Advantage of encouraging or promoting indigenous species is as follows:

- About 90 percent of the African farming sector is small-holders and to be viable and self-sustaining, small-holders need species that can be reproduced without complicated and expensive interventions.
- Promoting or encouraging dependence on non-native species will require hatchery facilities for propagation and will also exacerbate the fingerling supply problem.
- Inadequate hatchery reserve of brood stock (exotic species) will a major cause of inbreeding in cultured stock, whereas for indigenous species there is ready supply or reserves of brood stock that are already adapted to local environmental and climatic conditions for their reproduction.
- New feeds, disease therapies, reproduction techniques and sometimes even pond designs are needed when new species are introduced.
- Skilled scientists and extension personnel are needed to support the aquaculture development, and this may limit or put pressure on the number of researchers, whereas with the indigenous species, any student, experienced fish farmers or extension agent can get involved.

5.3 Research and Technology Development at NAC

National Aquaculture Center (NAC) and the field aquaculture stations are conducting research and development mainly oriented towards small scale aquaculture. It is time NAC identify and prioritize research issues that are more demand-driven for the development of commercial aquaculture. In order for aquaculture to meet the requirement of commercial operations or activities, the direction on research and technology should refocus and explore in a wider range in production systems, culture species and feed development to assist commercial farmers.

Efforts should be made to develop production and management technologies for local indigenous fish species. Substantial R & D have been conducted by NAC in the past on native fish species. These results of R & D should be commercially tested or transferred to evaluate economic and financial viability.

Local native fish species used in Malawi are in early stage of domestication, and therefore, their response to improved management or commercial fish farming is limited. Research and technology should emphasize on developing better performing strains through genetic enhancement methods and selective breeding methods.

Research should be conducted on development and application of improved broodstocks and hatchery management techniques to avoid inbreeding, hybridization, etc. Particularly, there is a need for more scientific research on *O. karongae* and *O. mossambicus* (a native fish in the Lower Shire area) as potential fish species for commercial fish farming.

Feed is crucial to successful development and commercialization of aquaculture. NAC should put more effort on important issues: efficiency in feed conversion; substitution of inexpensive locally available feed ingredients; recycling of by-products as well as waste materials.

NAC has identified development process and methodology for research (please refer Appendix-3).

5.4 Promotion of "Government – Private" joint research and technology development

One of the major constraints of NAC is availability of adequate fund for research and development; this is a common issue in most developing countries. Whenever possible, research and development should be conducted by the private sector. The advantages of promoting joint government-private sector research are achieving higher efficiency in existing research and development activities and that the results can be disseminated to all members, thereby giving incentive to contribute research fund. Private sector is composed of commercial fish farmers (producers), and service providers (feed makers), etc. Some of the areas for research and technology development are:

- Field trials of on-station experimental results for commercial viability
- Selective breeding and production of quality fish seed
- Formulation and development of domestic feed using local raw materials

5.5 Develop National Policy to Use Alien Species and Improved Strains for Aquaculture

Malawi is the only country in the sub-Saharan countries can safely claim has somewhat a clean slate in terms of absence of alien fish in the country, except for the common carp, in spite of the ban, fingerlings are still being produced and farmed on a experimental basis in Domasi and Kasinthula and some small holder farms in Lower Shire are still keeping and breeding and farming for sales. Otherwise, there are officially no alien fish species in Malawi, in comparison to the neighbouring countries (Zambia, Mozambique and Tanzania) that have introduced Nile Tilapia and Common carp for aquaculture use. By virtue of the Fisheries Act, introduction or transfers of alien fish species is prohibited officially. The National Fisheries and Aquaculture Policy (October 2001) too states that "to prohibit the introduction of live exotic fish species unless and until scientific evidence justifies otherwise". However, in view of the country's fisheries policy to promote and develop large fish farming, policy makers are also of the opinion why not introduce an alien fish species solely for aquaculture use? In addition, some investors are aware that the common carp is already in the country and is still being bred and farmed, and then what is the validity of the clause on prohibition in the Act?

There is a need for Malawi to develop a national policy on the use of alien fish species in aquaculture; a clear policy and legal framework will assist prospective investors in their decision. Therefore, Malawi must make it clear on its policy on the introduction, transfers and trans-border crossing of alien fish species in the interest of protection of biological diversity and of endemic (native) fish species as well as prospective investors wanting to enter into commercial aquaculture. In formulating the policies, the competent authorities must bear in mind or consider the international conventions and agreements as well as code of responsible fisheries for aquaculture. The proposed policies should include:

Appropriate policies should be in place for responsible development of aquaculture, in case Malawi decides to allow restricted use of exotic fish species in aquaculture (i.e. opton-2). The policy must be formulated within the national jurisdiction and legislations (Fisheries Act, Environment Act, Water Act, etc.), and to use international mechanisms for the control, movement and responsible use of alien species in aquatic system. The policy must include:

- appropriate legal administrative framework that facilitates the aquaculture development;
- type of fish for introduction;
- the area or site where it shall be farmed;
- process and procedure for risk analysis prior to approval

- the need to impart awareness to the general public and fisheries officers on the adverse impacts or consequences of exotic species with wild species

5.6 Develop National Guidelines of Commercial Aquaculture for Investors

An investor intending to take up or start-up commercial aquaculture needs to go through a process of getting property right, water right, aquaculture permit, import permit, tax exemption according the stipulated laws and legislation. This may take considerable time and cost on the part of the investor. It is, therefore, important to get these processes under a one-stop-shop or a single window approach.

For example, under Section 20 of the Fisheries Act a permit is required to operate an aquaculture establishment; then water right must be obtained under the Water Resources Act (No. 15 of 1969). The section is specifically stated to apply only to such aquaculture establishments as are prescribed by the Minister in the official Gazette. So if no establishments have yet been prescribed in the Gazette, there is no legal basis for requiring any permits. Currently, it seems there is no prescribed form for making an application. Then, for ensuring that proper environmental controls are imposed on aquaculture operations, an environmental impact assessment is required. These are fundamentally required for an operator to establish an aquaculture establishment. These process or steps would take considerable time and cost before the necessary papers and permits are ready for approval.

In order to ease the decision-making process, the competent authorities must formulate national guideline for commercial aquaculture that could easily followed and “business friendly” and all decisions relating to the grant of permit be subject to the discretion of the individual person (director). It is recommended the DoF should create a single window agency (one-stop-shop).

In a single window approach, the approval of an aquaculture project can request the applicant to satisfy the requirements of a number of different departments such as aquaculture permit under Fisheries Act, water right under Water Resource Act, an EIA under the Environment Management Act. By instituting a single window system to process the applications that require multiple approvals, it will prevent the applicant from being forced to bear unnecessary costs

II. RISK ASSESSMENT AND MANAGEMENT

1. Introduction of Alien Species and Risk Management in Malawi

1.1 Historical Background and Present Situation of Alien Species

In 1972 a pilot commercial fish farm was built at Kasinthula in the Lower Shire Valley. Growth trials were initiated with indigenous species, *Oreochromis shiranus, Tilapia rendalli,* and *Serranochromis robustus.* Yields of these species were so poor that in April 1975 a UNDP/FAO project entitled "Promotion of Integrated Fisheries Development" was presented to the Secretary for Agriculture and Natural Resources. The project's objective was to design commercial systems utilizing exotic fish species such as common carp, Chinese carp and *Oreochromis mossambicus* in polyculture with indigenous species. The Ministry expressed some concerns over introduction of exotic species but permission was granted contingent on assurances that Malawian fish species were not at risk. Concern over exotic fish species was reflected in the Malawian Fisheries Act, which discourages fish importations.

The Fisheries Department applied to the Secretary for Trade and Industry to import from Israel 100 common carp (a variety known as mirror carp)(*Cyprinus carpio*), 100 grass carp (*Ctenopharyngodon idella*), 100 silver carp (*Hypophthalmichthys molitrix*), and from South Africa, 100 *O. mossambicus*. On 24 April 1976, permission was granted, "Provided the importer will ensure that the named fish will not enter the natural waters/lakes of Malawi."

By June 1976, at Kasinthula, fish growth rates averaging in excess of 8 g/day for silver carp and 4 g/day for common carp (mirror carp) during a 150-day culture period were obtained. The Ministry agreed that research should continue and more fish be imported. Exotic tilapia (*O. mossambicus*) performed poorly and further trials were abandoned. Other tilapia species such as *O. niloticus* were requested for experimentation but no efforts were made to bring them into the country.

The need to introduce exotic fish species arose from strong pressure to make Kasinthula Fish Farm financially viable. Although an active national and international debate occurred over exotic fish species in Malawi, little thought was given by the consultant to the possible impact of carp to Malawi's natural ecosystem if the fish were distributed to farmers.

In 1984, the FD formulated conditions for distribution of common carp to farmers: no farmer would be allowed to breed the fish; and all carp fingerlings were to be supplied from government fisheries stations (Domasi and Kasinthula) at a nominal price.

The decision to import carp was influenced by the perceived absence of a fast-growing local species and a strong need to provide protein and farm employment where incomes and food production were low.

1.2 Situation in Regional Countries

Africa's fish genetic resources are important internationally. Cichlid fishes endemic to Africa comprise the foundation stocks of the world's growing tilapia aquaculture production. Many tilapia stocks have deteriorated, and need fresh input from Africa, which holds the gene bank for the future of tilapia aquaculture.

According to FAO database some 139 species have been introduced into 42 African countries consisting of 79% of finfish, 7% mollusks and 9% crustaceans. The most often introduced species are common carp with 28 records, rainbow trout 19 records, large mouth bass 19 records, Nile tilapia 17 records and grass carp 15 records. Nile tilapia and common carp have been introduced in Zambia, Zimbabwe, Mozambique, and Tanzania. The reason for introduction is mainly for aquaculture use and their status on establishment in the wild including on the ecological effect is not clear due to absence of data. In the case of Malawi, common carp was introduced in 1979 from Israel for aquaculture use, and it is not established in the wild although there are rumors of escape from farms in the Lower Shire area.

Some 20 African countries have introduced common carp for aquaculture since the 1940s. Carp were introduced for culture in cooler areas and for supplementing tilapia yields. Initially carp introductions to sub-Saharan Africa were banned because of danger to endemic species if carp escaped. With rapid development of aquaculture in the 1980s, donor agencies and consultants promoted known species mainly because of the low cost for development compared with that of developing new systems for little known indigenous species. Hence, common carp was introduced to Malawi despite the country's having the world's most diverse freshwater fish fauna.

A review of exotic fish species introduced for aquaculture use in the regional countries, namely Zambia, Zimbabwe and Mozambique is outlined below. Refer Figure -1 on the presence of alien fish species in some sub-Saharan countries.

(1) Zambia

The aquaculture in Zambia is comprised of commercial scale farmers with strong financial backing often owned by multi-national corporations and operated by expatriates, mid-level farmers, and small-scale village and family farms. Aquaculture involves mainly the farming of cichlids; *Oreochromis andersonii*, *O. macrochir* and *Tilapia rendalli* using integrated system. Aquaculture production estimated at 4,200 tons annually and this accounts for about 6 percent of the national fish catch. In order to improve the general performance of aquaculture, exotic species have been introduced and these are the common carp, *Cyprinus carpio* and Nile tilapia, *Oreochromis niloticus*. The common carp has fast growth rate and can reach table size after three months where as the local species can reach table size after six months. The Nile Tilapia is one of the most investigated species in aquaculture and the conditions required for its culture are well known. This appears to be the main reason for its introduction and culture in Zambia. The fisheries department does not keep accurate data and information on the aquaculture production. According to FAO fisheries statistics, the aquaculture production in 2001 was 4,200 tons; of which Nile tilapia and common carp accounted for 220 tons and 220 tons, respectively.

Common carp (mirror carp) was introduced in Zambia from Malawi and are farmed in several areas. Fry and fingerlings of common carp are produced and distributed by the NARDC in Mwekera in the Copper belt region, while there are farms that conduct selective breeding and produces their own fry and fingerlings. Chinese carp, namely grass carp is not widely cultured and it is only seen as an activity for the commercial scale fish farmers. It was introduced in the 1980s with the purpose of meeting market demand for large fish and introducing into production ponds would improve water quality and remove some aquatic vegetation. The commercial sector is able to manage artificial spawning procedures, marketing and distribution of new species such as Chinese carps. Nile tilapia, introduced in 1980, is being widely cultured. Besides the indigenous tilapia species, *Oreochromis andersonii* that is cultured by many, *Oreochromis niloticus* is much sought after fish not only by commercial investors but also by mid-level farmers and small-scale farmers because of its long tradition of domestication and desirable growth traits. According to FAO statistics, 220 tons were produced in 2001; it could be even more as fisheries department is lacking in data collection of aquaculture production.

Kafue Fish Farm Ltd., located in Lusaka region, cultures common carp in addition to *O. andersonii*, *Ctenopharyngodon idella*. This farm does not culture Nile tilapia. The farm produces fingerlings for its own use and sells surplus to other farms. The farm produces in a year about 40 tons of common carp and a ton of grass carp.

Macadamia Farms, located in Kitwe, Copperbelt, also cultures common carp in addition to *O. andersonii*, and its production volume depends on the availability of fingerlings; the farm gets fingerlings from NARDC. The farm has keen interest to increase common carp production, but there is a shortage of carp fingerlings.

Chrindue Bream Farm: Located in Chrindue about 100 km from Lake Kariba, specializes in the selective breeding and production of fry and fingerlings of Nile tilapia. The farm distributes fingerlings to commercial and mid-level farmers.

Floating cage production: Several floating cage operators have emerged in recent years; each operator produces less than 100 tons a year. These operators are diversifying from other activity mainly from Kapenta fishing. Their interest into culturing of Nile tilapia is attributed to high market demand for fish in Zambia as well as good growth performance.

NARDC of Fisheries Department, located in Mwekera in Copperbelt, conducts research, training and produces fry and fingerlings for distribution. The Center has broodstocks of grass carp, common carp and Nile tilapia besides the indigenous fish species for research and seed production. Although there is a high demand for fish seed including the Nile tilapia and common carp, the center is not operating and producing according to its capacity due to budgetary constraints. There is not much demand for grass carp from mid-level and small-scale farmers. The center has currently 300 names on its distribution list for not only common carps but also for *O. andersonii* and *O. niloticus*.

Rural Aquaculture Project (USAID)

US Peace Corp/Zambia developed Rural Aquaculture Promotion (RAP) in response to a request from the Zambian Department of Fisheries fro human resource assistance in the aquaculture sector. The assistance began in June 1996 with a needs assessment. Based on the positive and encouraging results of this assessment, and in December 1997, 20 RAP volunteers were posted in five provinces in Zambia except the Eastern. In 2004, 53 volunteers are serving the project, working mainly with individual rural farming families, DoF staff and farmer associations. These volunteers are offered three-month training at NARDC in Mwekera (Kitwe, Copperbelt) before assigning them to respective rural areas.

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How Nile tilapia got selected for the RAP? RAP is based its aquaculture technical standards on the experiences gained from similar projects in West and Central Africa. The basic standard called the "Zaire Model" involved the monoculture of the most productive tilapia fish species available. RAP researched into existing information and experiences to compare the productive potential of existing species as a basis for making decision on which to promote. However, the existing body of knowledge and information was not helpful to make objective comparisons of the species. Therefore, in 1997, RAP prepared guidelines for trials aimed at comparing the total production (harvestable weight) and number of fingerlings produced among the four available tilapias: *O. machrochir*, *O. niloticus*, *O. andersonii* and *T. rendalli*. This experiment was implemented at a government station in Northern Province. Unfortunately, due to some unknown circumstance, the trials were not executed according to the planned experimental conditions and the results obtained were unreliable. Despite this shortcoming, RAP and the Fisheries Department decided to promote *O. niloticus*.

An international group of concerned scientists raised the issue on the introduction of non-native fish into Zambia to Peace Corps in Washington and further stated that introduced fish have caused a tremendous loss of freshwater biodiversity worldwide. This group advised US Peace Corps to eliminate the introduction of exotic species in future, and recommended Peace Corps to promote and conduct responsible aquaculture practices and to use only native fish.

On the status of introduced and trans-located species in Zambia, there are about 26 introduced fish species in Zambia; among which the species that play a significant role in aquaculture are *Oreochromis niloticus* (Nile tilapia), *Cyprinus carpio* (Common carp) and *Ctenopharyngodon idella* (grass carp).

Fish species introductions have played a significant role in the Zambian fisheries. Several introductions have taken place; some of these introductions have been successful with record of significant increases in fish production, particularly Nile tilapia and common carp. There are also fish species introductions that have caused ecological damage. *Oreochromis niloticus*, a widely used in aquaculture, is reported to have been accidentally in the Kafue Floodplain from aquaculture activities. It is certain that there is competition between the new species with other cichlid species in the fishery. *Oreochromis niloticus* farmed in Mazabuka area has escaped into the Kafue River and is spreading westwards along the Kafue Flats. There may not only be competition between this species and the indigenous species of the area but hybridization can not be ruled out and this can alter the genetic composition of the cichlid species of the Kafue Flats and the catchment areas.

Although farmers and fisheries officers have reported that no common carp are present in natural water bodies and rivers including the Lake Kariba, and that this species, in case of escape or accidental release, would probably not establish reproducing population in Zambian waters and that it could not reproduce an assisted in ponds, there are cases of self reproducing populations of mirror carps in the pond St. Joseph Mission in the Copperbelt). This calls for a precautionary approach to fisheries management and development and implementation of studies aimed at assessing the impacts of introduced species.

(2) Zimbabwe

Several aquaculture activities using tilapia and carps are established. Commercial fish farming of *Oreochromis niloticus* is established especially around Lake Kariba on the Zimbabwean side. The Lake Kariba Fisheries Research Institute had discouraged the use of *Oreochromis niloticus* in Lake Kariba area and recommended the use of local tilapia species. Local species of tilapia were tried in Kariba Bream Farm, but given up in favour of Nile tilapia. FAO statistics shows a total aquaculture production of 200 tons in 2001, of which Nile tilapia comprises 80 tons. In fact the tilapia production should be more as Lake Harvest's floating cage culture of Nile tilapia amounts to about 3,000 tons a year.

Two species of Chinese carp (big head and silver carp) have been introduced in farms along Lake Kariba. These carps had limited use in aquaculture because of problems with hatching rate and mortality of broodstocks. In addition, it was also doubted that local people would accept carp as food, but there is a desire by farms to use grass carps to clean up pond vegetation.

Common carp was introduced in the 1920s and are supposed to be prevalent in fish farms. However, none are thought to be in Lake Kariba. According to FAO Fisheries Circular No. 863 (1993) common carp are continued to be stocked occasionally by government agencies in the reservoirs, but are not extremely prolific and not thought to be spreading outside of the areas of their original introductions.

(3) Mozambique

Nile tilapia and common carp have been introduced in Mozambique; especially Nile tilapia for aquaculture (source is unknown). Common carps were known to have been produced for stocking and dispersal to interested farmers by the fisheries department; original introduction of common carp was probably from South Africa. Common carps appeared to have been established in many of rivers; but how prolific they are in rivers is unclear. Chinese carps were introduced in 1991 from Cuba; which had its introduction from the former Soviet Union during the mid 1960's

1.3 Fisheries Legislation Concerning the Introduction and Transfer of Live Aquatic Species, with reference to Malawi and neighbours

The existing legislation and associated regulations concerning the transfer and introduction of aquatic species at international, regional, bilateral and national level are discussed here as to whether enacted, enforced or not, with specific reference to Malawi.

(1) International Agreement

The International Convention on Biodiversity, which went into force in December 1993, is probably the most relevant piece of international legislation. Malawi and Zambia are the only two SADC countries to have ratified the Convention. This convention recognizes the value of natural and domesticated biological diversity and acknowledges the sovereignty of countries over their species.

The Convention also addresses the issues of the introduction and transfer of species. Article 8 (g) states that "Each party ….. shall Establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology .. and (h) Prevention the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". In addition, the Treaty (Convention) provides for cooperation "in respect of areas beyond national jurisdiction and on other matters of mutual interest, for the conservation and sustainable use of biological diversity". The mechanisms of such cooperation have to be worked out by the countries concerned.

(2) Regional Agreements

SADC (Southern African Development Cooperation) was set up by treaty in 1980, and Malawi is a party to the treaty. One of the main objectives of the Treaty is to ensure that development does not impair the diversity and richness of the region's natural resource base and the environment. Article 5.1.g of the Treaty provides for the achievement of "sustainable utilization of natural resources and effective protection of the environment".

(3) Bilateral Agreements

Bilateral agreements concerning the management of the resources in shared rivers, lakes, water bodies, and the river basins offer the opportunity for countries within the region to regulate or prohibit the introduction and transfer of aquatic species. Cooperation mechanisms and/or joint commissions exist for most of the shared lakes in the region i.e. Lake Tanganyika, Lake Mweru, Lake Kariba, and Lake Nyssa/Malawi. These mechanisms enable those countries bordering the lakes, to collaborate in activities and cooperate over management of the resources of the lake. However, there are no legally binding agreements for Lake Kariba (Zambia and Zimbabwe), Lake Nyssa/Malawi (Tanzania, Mozambique and Malawi).

(4) Malawi's Obligation to International Agreements & National Legislation

Malawi adheres to the international principles of agreements and conventions. The government has signed and ratified the Convention on Biological Diversity (CBD) whose objectives are the conservation of biodiversity, sustainable use of its components and the fair and equitable sharing of the benefits arising from the utilization of the genetic resources. In addition, Malawi is a signatory of the following conventions related to biological diversity.

- Convention of Wetlands of International Importance (RAMSAR) (ratified in 1997, and since then Lake Chilwa has been declared a Ramsar Site)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Convention on the World Heritage Sites (Lake Malawi National Park is a World Heritage Site
- United Nations Framework Convention on Climate Change (UNFCCC)
- The Convention of Desertification and Drought (CCD)
- FAO International undertaking on Plant Genetic Resources

- Montreal Protocol for the Protection of the Ozone Layer
- Convention of International Plant Protection
- United Nations Convention on the Law of the Sea

There are legislations at the national level governing the import, export and transfer of species for most of the countries in the SADC region, and that includes live fish. For the countries surrounding Malawi, namely, Zambia, Mozambique and Tanzania, the national legislations indicate the requirement of permits of import and transfer of aquatic species. The fisheries sector including aquaculture operates within the Fisheries Management and Conservation Act (No 25 of 1997); and Fisheries Conservation and Management Regulations 1999.

Although the legal framework is in place to control the introduction and transfer of fish, there are difficulties with enforcing legislation in the region, including Malawi whose department lack resources to carry out the duties. The difficulties include lack of qualified personnel, lack of resources to monitor fish farming and stocking activities in private water bodies (ponds).

1.4 Risk Management and Quarantine System in Malawi

Under Part XI, section 41: Prohibition of transfer, etc. of fish, of the Fisheries Conservation and Management Act states that no person shall, without a permit granted by the Director – (a) transfer fish from an aquacultural establishment or any other water to any different aquacultural establishment or water; (b) stock any water with fish; or (c) introduce into any water any fish not indigenous thereto. By virtue of this section, it implies that any importation or introduction of alien fish species is prohibited. It could also imply that any translocation or transfer within Malawi of any fish (alien) already in the country.

In addition Section 35(1) of the Environmental Management Act stipulates that the actions that Minister of Environment should undertake to ensure that Malawi's biological diversity is conserved. Section 35(2) gives the guidelines that should be followed in protecting and conserving indigenous biodiversity including that of aquatic ecosystems in subsection (2)(b) and points to the need to control the importation of alien species in subsection (2)(e).

In both Acts the Director of Fisheries (Fisheries Conservation and Management Act) and the Minister (Environmental Management Act) are the authoritative bodies that issue permits based on the availability of relevant information for decision making. This means that in making such a decision relevant codes or practices, international conventions and protocols to which Malawi is a signatory party, would be adhered to. Therefore, regulatory mechanisms to ensure compliance should be in place.

Currently there is no risk management and quarantine system in Malawi; it is not stipulated in both Acts. There is also no regulatory mechanisms (no clear code of practice on growing, handling and management of fish species) in place in case a permit is issued for an import of live aquatic organisms, although the current facilities at NAC would be used for quarantining.

1.5 Risk Management in Other Countries

There is no risk management and quarantine system in the immediate surrounding countries, although the commercial fish farming of exotic fish species (Nile tilapia and common carp) is developed in comparison to Malawi.

Zambia is governed by the Fisheries Act of 1974 (Zambia Fisheries Act, chapter No. 314 of the Laws of Zambia). This legislation is based on the colonial Fisheries Ordinance of 1962 and dates from a time when commercial aquaculture was not contemplated. Therefore, the Fisheries Act does not contain any substantive provisions relating to aquaculture, though the Minister is granted a power under section 21.2 (k) of the Act to regulate and control fish culture. Incidentally, the Act affects the aquaculture industry through a prohibition against the introduction of any species of fish or importation of any live fish without the written permission of the Minster. The development of the aquaculture industry so far has not been facilitated by the legislation. However, a new Fisheries Legislation has been drafted and it is expected to be introduced in Parliament any time. There is no risk management and quarantine system although the commercial fish farming of exotic fish species (Nile tilapia and common carp) is developed in comparison to Malawi.

2. Precautionary Approach to Use of Exotic Fish Species

There are two schools of thoughts in Malawi currently as explained earlier whether to introduce an alien fish species or to encourage the use of local native culturable fish species in aquaculture. No doubt introduced fish species are an established means to increase productivity and generate income in aquaculture. However, both the intentional and accidental introductions are recognized as serious threats to aquatic biological diversity. Therefore, management must address both beneficial and negative aspects of species introductions. However, there is an inadequate knowledge base on which to base policy and management decisions. Two basic unknowns exist concerning an introduced species: i) its impact on the receiving ecosystem and ii) its performance in the new ecosystem. Related to these unknowns are three general levels of uncertainty: i) uncertainty that arises from a lack of basic information; ii) uncertainty that arises from unknown interactions within a given system; iii) uncertainty that arises from shifts and interactions in physical, biological, social and political systems.

What needs to be done before making a hasty decision and regret later?

There are several precautionary approaches that may help minimize adverse effects from exotic species. These range from getting policy and decision-makers to think about an introduction through education and use of a code of practice, documenting native resources that may be affected, maintaining registries of exotic species and their effects, up to incorporation of protocols and guidelines for implementing codes of practice and environmental impact assessments in legislation. Guidelines and codes of practice represent one of the best precautionary activities available for species introductions.

2.1 Apply the ICES/EIFAC Code of Practices

Prior to making decision especially on introduction of the alien species (say common carp and Nile tilapia), an effort must be made to apply a logical framework using the ICES/EIFAC Code of Practice (Turner 1988), and this code recommends the use of a decision tree and rating system, and is one of the means of evaluating a proposed introduction or transfer. As a model case, attempt on use of common carp in aquaculture was made as indicated below.

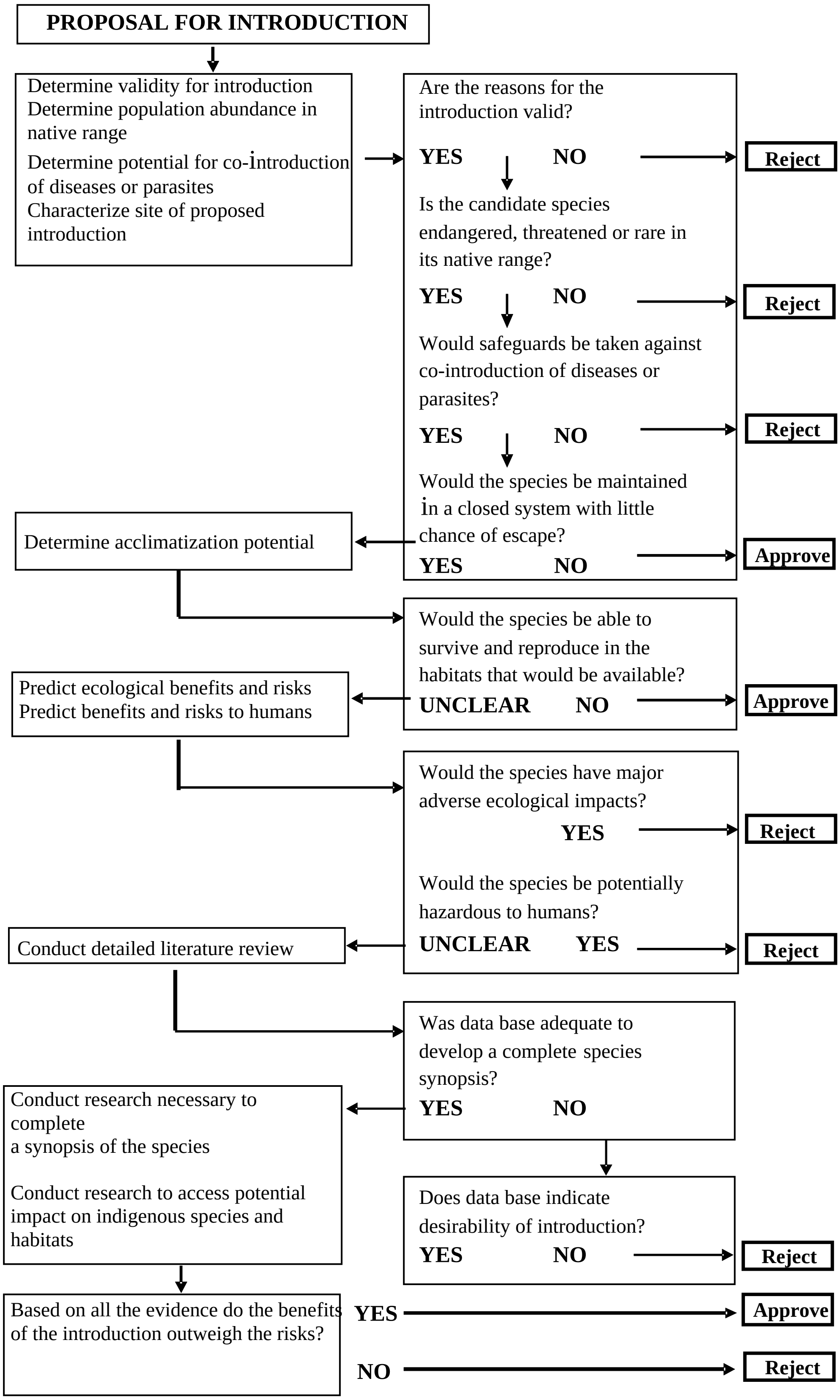

Figure 2.1 Flowchart showing steps on proposal for introduction

Table 2.1 Timeframe of activities

Review Level-1		Decision
1. Is the need to use or introduce common carp valid and there are no native species available that could serve the stated need?	- The need to increase fish supply as capture fish production is declining - Current aquaculture productivity of native species is low - Native species are suited for commercial scale culture	Proposed use of common carp appears to “probably” satisfy a valid need in terms of fish production.
2. Is common carp safe from over-exploitation in its native range?	- Common carp has been introduced and farmed extensively in many countries. - It was introduced in Malawi and exists in some fish farms (but banned).	
3. Are safeguards adequate to guard against importation of disease / parasites?	- No quarantine system or measures for importation of organisms - Safeguards are non-existent at airports or borders - Preliminary screening of samples could be undertaken at NAC.	
4. Would the introduction be limited to closed system?	- Use would be in a closed system - pond based culture - Fry and fingerlings produced would be used	

Review Level-2		Decision
5. Would the common carp be unable to establish a self-sustaining population in the range of habitats that would be available	- Common carps are known to reproduce naturally in the wild if precise requirements for reproduction. -	

Review Level-3		Decision
6. Would the common carp have mostly positive ecological impacts?	- - -	
7. Would most consequences of the introduction be beneficial to humans?		

Review Level-4		Decision
8. Is data base adequate to develop complete species synopsis?	-. - -	
9. Does data base indicate desirability for introduction?		
10. Would benefits exceed risks?		

2.2 What is the Government Policy of the Introduction or Transfer or Commitment or Obligation to International Conventions and Agreements?

The government's policy has a bearing on the international conventions and agreements to which it has agreed and signed; International instruments (conventions) and Code of Practices to which Malawi is a signatory are indicated below.

(1) Binding Instruments

- Convention on Biological Diversity (CBD)
- Cartagena Protocol on Biosafety
- Convention of Wetlands of International Importance (RAMSAR) (ratified in 1997, and since then Lake Chilwa has been declared a Ramsar Site)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- United Nations Convention on the Law of the Sea

(2) Non-Binding (Voluntary) Instruments

- ICES Code of Practice on the Introductions and Transfers of Marine Organisms (1994)
- FAO Code of Conduct for Responsible Fisheries (1995) Art. 9 (Aquaculture)
- IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion (1995)
- IUCN/SSC Guidelines for the Re-introductions (1995)
- CBD Subsidiary Body on Scientific, Technical & Technological Advice Guidelines (1999)

The binding conventions have legal status, and Malawi has an obligation to adhere and abide to the international principles of the conventions signed when it formulates policy on the use of alien species. The "Code of Practices" has no legal status in most countries and is regulations but a voluntary system which can be adopted to address a particular problem. In addition, there are existing laws, Fisheries Conservation and Management Act and Environmental Management Act to which policy makers had to consider.

The fundamental objectives to follow these conventions and code of practices are to conserve biological biodiversity; sustainable use of resources; to limit the impacts of the introduction/transfer on biodiversity (to ensure the resident fauna/flora is not adversely impacted); to ensure the introduction/transfer meets the socio-economic development goal. In other words, Malawi, particularly as a signatory of CBD, is committed to developing national strategies, plans or programmes for the conservation and sustainable use of biological diversity. The Environmental Affairs Department has prepared and reviewing National Biodiversity Action Plan; once it is finalized the respective departments including the Fisheries Department will have to appropriately formulate policy and prepare action plans.

2.3 What Steps to Take?

The recommended procedure involves four steps and they are inter-related (PROPOSAL →EVALUATION → REVIEW → DECISION). The principle of the procedure is quite simple. When there is a proposal to introduce or transfer an aquatic organism it is subjected to evaluation (before it occurs) followed by an independent review of the evaluation and a decision on whether or not to proceed with the introduction or transfer (and by what means, e.g. quarantine considerations, etc.

PROPOSAL
to introduce or transfer
(what species/strain, where, why, how, anticipated impacts)

↓

EVALUATION
In depth analysis of the benefits
and risks in ecological, genetic and socioeconomic terms and proposed quarantine arrangements

↓

INDEPENDENT REVIEW
Review of the proposal and evaluation, checking its thoroughness, accuracy, advising on the appropriateness of the proposal and making recommendations as to how to proceed

↓

DECISION
a decision by the appropriate decision making authority on whether to proceed and under what conditions (quarantine, containment, monitoring and reporting)

3. Risk Assessment

There is always a risk associated with the introductions or movements of aquatic animals including fish. Risks should be assessed using scientific data and information. In the event that there is a lack of sufficient scientific data, the precautionary approach should be used.

Risk assessment is a part of overall risk analysis, which consists of 4 interrelated components:

- Hazard identification
- Risk assessment
- Risk management
- Risk communication

Hazard identification, risk assessment and risk management form the **CORE** of the risk analysis, while risk communication is a continuous activity.

Hazard identification: What is hazard? As an example "Introduction of alien fish species in to Malawi" is a hazard.

Risk Assessment: is "the process of identifying and estimating the risks associated with the importation (introduction) of a commodity and evaluating the consequences of taking those risks."

Once the potential hazards associated with the introduction fish species have been identified, the next step is to estimate, for each hazard, the likelihood of entry, establishment and spread as well as likely biological and economic consequences that would result.

Potential hazard	Likelihood of entry	Likelihood of establishment	Likelihood of spreading	Biological and economical consequences

Risk Assessment is comprised of four components:

- Release assessment
- Exposure assessment
- Consequence assessment
- Risk estimation

Release assessment – describes biological pathway(s) necessary for an introduced activity to "release" a hazard into a particular environment and estimates the likelihood of that complete process occurring.

Exposure assessment - describes biological pathway(s) necessary for exposure of humans and aquatic and terrestrial animals in the imported country to the hazards and estimates the likelihood of the exposure(s) occurring and of the spread or establishment of the hazard.

Consequence assessment – identifies the potential biological, environmental and economic consequences. (or exposure to a hazard result in adverse, health, environmental or socio-economic consequences.).

Risk estimation – integrates the results of the release assessment, exposure assessment and consequence assessment to produce overall measures of risks associated with the hazards identified.

Risk Management:

Risk management is … "the process of identifying, selecting and implementing measures that can be applied to reduce the level of risk." Risk Management consists of four components:

- Risk evaluation
- Option evaluation
- Implementation
- Monitoring and review

Risk evaluation – comparing the unmitigated risk as estimated in the risk assessment with the importing country's appropriate level of protection (ALOP). Each hazard is compared with the ALOP which is the level or risk considered acceptable to the country.

Option evaluation – identify, evaluate the efficacy and feasibility of, and select measures to reduce the risk associated with the introduction to below the importing country's ALOP.

The measures could be importing eggs only, requiring quarantine and inspection at origin, requiring use of specific diagnostic tests and standards, requiring pre-shipment and / or post-shipment treatments

Implementation and Monitoring and Review – follow through the risk management decision and ensure that the risk management measure are in place while monitoring and review is the on-going process by which the risk management measures are continuously audited to ensure that the results are achieved.

A scenario of risk analysis, incase of introduction of common carp, is shown in the following

Table 3.1 Risk Analysis of Common Carp (An example)

HAZARD IDENTIFICATION		RISK ASSESSMENT			RISK MANAGMENT
What Hazards?		Risk (Who will be harmed?)	How?	Degree	Precautions/Measures
Introduction of Exotic species (Common carp in Aquaculture)	Existing in Zambia, Zimbabwe, Mozambique (possibility of transfer intentionally or accidentally) Common carp introduced in 1980s; banned in 1992; currently farmed in some locations)	Lake Malawi Lake Chilwa Other water bodies	- Existing native cichlid species (potential threat to biodiversity) - Ecological / biological impact - Likely to be pest / nuisance species (like in Australia by common carp)	High/low/medium (based on the cases or consequences observed in other countries) - Common carp is present in some farms and fingerlings are being produced. - Fingerlings are distributed farmer to farmer (extent of distribution is not known.) - High risk of uncontrolled movement or distribution. - High risk of escaping to the wild	Legal requirements on prevention of introductions and transfers - Fisheries Act - Strict legislation to check/enforce - Institute quarantine - Institute cross-border control on movements of live organisms - Reasonable practicable measures in FA Application of Code of Practices for Transfer / Introduction of Exotic Species

III. RECOMMENDATIONS TO MASTER PLAN

The government has recognized and underscored the potential and catalytic role aquaculture can play in food security and poverty alleviation and contribute also to the country economic development. It is therefore expected the aquaculture production would augment the domestic fish supply which is on a declining trend since late 1970s, and it has resulted in high fish price and high fish demand in both rural and urban areas. Against the many issues and problems in both technical and non-technical areas facing the aquaculture sector, it is highly recommended the Malawi initiate the path to promote and develop the commercial aquaculture. The recommendations to master plan are:

- To conduct aquaculture technology development immediately on the local culturable indigenous fish species for commercial fish farming (recommended the use of on-station R & D obtained so far) in collaboration with commercial fish farmer.
- To conduct more applied scientific research on O. karongae and O. mossambicus as potential indigenous species for commercial fish farming (collaborative research with commercial fish farmers highly recommended).
- To conduct research and trial on formulated fish feed using local ingredients, as feed is the critical factor in production cost.
- For the above, promote and conduct ‘government-private” joint research and technology development using the facilities and equipment at NAC and other field stations (even to the extent of leasing the facilities to private commercial farmer).
- To formulate and enact enabling aquaculture policies and legal framework that are “business friendly” and conducive to private sector; develop a national guideline for commercial aquaculture that will guide prospective investors to aquaculture without causing much time and money and a single window agency to process application requiring multiple approvals.
- On the use of alien (non-native) fish species in aquaculture, the DoF should as far as possible avoid the introduction of alien fish species, and instead encourage the use of only indigenous fish species in view of the protection of biodiversity of Lake Malawi and other water bodies. Document the information on the impact of alien fish species that are farmed in bordering countries, and formulate measures to prevent cross-border transfer or movement of live fish species, and strictly follow the international conventions and protocols, and conduct risk analysis prior to approval.
- The presence of common carp in Malawi (alien fish species) needs to be reviewed and conduct risk analysis on its future status in Malawi.
- *Oreochromis mossambicus*, an indigenous fish species in the Lower Shire, should be considered for aquaculture especially in the lower shire in view of the recent advances in the proved strains of the species

Attachment

Attachment 1

GUIDELINE ON THE FORMULATION OF THE ENVIRONMENTAL IMPACT ASSESSMENT IN AQUACULTURE

Qualification

Any aquaculture establishment that occupies more than 4 hectares or a production whose output exceeds 4 tonnes per hectare should have an EIA.

The EIA should comprise the following;

Introduction

The introduction contains the following information

a. Promoter (s)

Indicate the owner (s) of the enterprise.

b. Background

The background must describe the whole project, starting from production, facilities, equipment, markets and marketing and administration. The background must also justify the importance of the project and how it fits to the national goals such as poverty alleviation, import substitution, employment generation, women empowerment etc.

c. Current Environmental Situation

This section must contain the following: wildlife, fisheries, forestry, soils, temperature / climate, river and their flow variability, water quality and quantity, noise, agriculture, flora / fauna; and the socio-economic situation (active population, employment, education, public health, quality of life, culture and religion, gender development, local leaders and their environmental concerns towards the project). And any other environmental factors in the area

d. Potential impact identification and their mitigation measures

This section must contain project inputs; project activities; management activities; and project outputs

e. Environmental Management plan

MODEL OF TERMS OF REFERENCE FOR EIA IN AQUACULTURE

The EIA must contain the following:

- A brief description of the project including a detailed description of the facilities.
- A review of relevant background information and references.
- A summary of the environmental baseline data.
- A concise and accurate description of the features of the project and its structures.
- A qualitative and quantitative evaluation of the potential environmental impacts identified as direct, indirect, short and long term and cumulative effects, according to the best information available.
- A description of the structures and management measures needed to ensure minimum impact throughout the life of the project. This is the 'Core' of the report and should include consideration of all reasonable alternatives and the extent to which public consultation is used in the management measures.
- Undertake public consultation to ensure that all stakeholders, interested and affected parties are consulted. Consultations must include stakeholders at the site and those surrounding the site. Government line Ministries that are affected, NGOs and local leaders.
- A cost benefit analysis of the recommended structures and mismanagement measures needed to make the project environmentally acceptable.

The structure of the report should follow the guidelines provided in the Malawi EIA guidelines. It will basically consist of an Environment Impact Assessment (EIA) and Environment Management Plan (EMP). The EMP must be practical and cost effective. It must identify the information needed to guide management decisions and the current costs and sources of financing for the EMP and its monitoring tasks. It should clearly indicate the responsibilities for lead agencies, stakeholders and any training needs that should be undertaken to ensure its proper implementation.

Ten draft copies are submitted to the Environmental Affairs Department (EAD). The EAD circulates to experts that review the draft and make recommendations.

The recommendations are incorporated into the report and the final document is submitted to EAD which presents the report to the Taskforce on Conservation of the Environment (TCE) that finally approves the project and a certificate is issued by the Director of EAD.

Attachment 2
Article 9 of FAO Code of Responsible Fisheries

Article 9: AQUACULTURE DEVELOPMENT

9.1 Responsible development of aquaculture, including culture-based fisheries, in areas under national jurisdiction

9.1.1 States should establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture.

9.1.2 States should promote responsible development and management of aquaculture, including an advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best available scientific information.

9.1.3 States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities.

9.1.4 States should ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments.

9.1.5 States should establish effective procedures specific to aquaculture to undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from water extraction, land use, discharge of effluents, use of drugs and chemicals, and other aquaculture activities.

9.2 Responsible development of aquaculture including culture-based fisheries within transboundary aquatic ecosystems

9.2.1 States should protect transboundary aquatic ecosystems by supporting responsible aquaculture practices within their national jurisdiction and by cooperation in the promotion of sustainable aquaculture practices.

9.2.2 States should, with due respect to their neighbouring States, and in accordance with international law, ensure responsible choice of species, siting and management of aquaculture activities which could affect transboundary aquatic ecosystems.

9.2.3 States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems.

9.2.4 States should establish appropriate mechanisms, such as databases and information networks to collect, share and disseminate data related to their aquaculture activities to facilitate cooperation on planning for aquaculture development at the national, subregional, regional and global level.

9.2.5 States should cooperate in the development of appropriate mechanisms, when required, to monitor the impacts of inputs used in aqaculture.

9.3 Use of aquatic genetic resources for the purposes of aquaculture including culture-based fisheries

9.3.1 States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks.

9.3.2 States should cooperate in the elaboration, adoption and implementation of international codes of practice and procedures for introductions and transfers of aquatic organisms.

9.3.3 States should, in order to minimize risks of disease transfer and other adverse effects on wild and cultured stocks, encourage adoption of appropriate practices in the genetic improvement of broodstocks, the introduction of non-native species, and in the production, sale and transport of eggs, larvae or fry, broodstock or other live materials. States should facilitate the preparation and implementation of appropriate national codes of practice and procedures to this effect.

9.3.4 States should promote the use of appropriate procedures for the selection of broodstock and the production of eggs, larvae and fry.

9.3.5 States should, where appropriate, promote research and, when feasible, the development of culture techniques for endangered species to protect, rehabilitate and enhance their stocks, taking into account the critical need to conserve genetic diversity of endangered species.

9.4 Responsible aquaculture at the production level

9.4.1 States should promote responsible aquaculture practices in support of rural communities, producer organizations and fish farmers.

9.4.2 States should promote active participation of fishfarmers and their communities in the development of responsible aquaculture management practices.

9.4.3 States should promote efforts which improve selection and use of appropriate feeds, feed additives and fertilizers, including manures.

9.4.4 States should promote effective farm and fish health management practices favouring hygienic measures and vaccines. Safe, effective and minimal use of therapeutants, hormones and drugs, antibiotics and other disease control chemicals should be ensured.

9.4.5 States should regulate the use of chemical inputs in aquaculture which are hazardous to human health and the environment.

9.4.6 States should require that the disposal of wastes such as offal, sludge, dead or diseased fish, excess veterinary drugs and other hazardous chemical inputs does not constitute a hazard to human health and the environment.

9.4.7 States should ensure the food safety of aquaculture products and promote efforts which maintain product quality and improve their value through particular care before and during harvesting and on-site processing and in storage and transport of the products.

Attachment 3

DEVELOPMENT PROCESS OF RESEARCH MASTER PLAN AND ITS METHOD

Concept Paper
By
The National Aquaculture Centre
Authors
A.O. Maluwa, S. Unyolo, F. Kapute, H. Zidana, G. Ntenjera and G. Khota.

The selected species are *Oreochromis mossambicus* and *Oreochromis karongae*. There is quite a lot of information on *O. mossambicus* as a candidate species for commercial and intensive aquaculture, however, information on *O. karongae* as a species for commercial aquaculture under intensive systems is limited. This concept paper has outlines the areas that need further research for the species to be farmed at commercial levels under intensive systems.

1. Biology and Taxonomy

<u>Introduction</u>

Oreochromis karongae is a known as Lake Malawi Chambo, is one of a group of four closely related tilapias of the genus *Oreochromis* (Nyasalapia) flock that was described by Trewavas in 1983. This fish occur only in Lakes Malawi and Malombe. There are other related species which are *O. squampinnis, O. lidole and O. saka*, according to the classification by Trewavas, 1983, which all belong to the Chambo group. However, Turner and Robinson (1990) reported that *O. saka* is synonymous to *O. karongae* and that there are only 3 species within the Chambo group, namely, *O. karongae*, *O. lidole* and *O. squamipinnis*.

<u>Biology</u>

In nature, *O. karongae* breeds from August to November (in hot weather before rains) on weedy inshore areas. The minimum and average breeding sizes are 25cm and 27.5cm respectively and breeding is observed after three years of age (Lowe 1952). Average period from egg laying to release of young is about four weeks. Ovaries for spent females are dark brown and degenerate after spawning suggesting that all eggs are shed at once. The fecundity is between 276-330 eggs. Fish take about a month from the time that they start to develop the breeding color to the time that they become fully ripe.

In ponds, *O. karongae* has been reported to breed from September to March and the latest results from Maldeco show that in ponds along the lakeshore, *O. karongae* breeds even in the cool months of the year, (May to August). This seems to suggest that temperature is the most important water quality parameter in order to optimize fry production from the species. As a mouth brooder with large eggs, *O. karongae* has low fecundity, therefore more broodstock should used to maximize fingerling production.

2. Research Areas

<u>Taxonomy</u>

The most difficult time to distinguish the species within the Chambo group is when they are less that 15 cm and when they are not breeding. During breeding, there is a problem to distinguish between females of *O. karongae* and *O. squamipinnis*. A guide on the classification of the Chambo species is shown in table 1.

Table 1 below compares morphological characteristics of the three species.

Table 1. Morphological characteristics that are used to identify the three *Oreochromis* species

	O. lidole	*O. squamipinnis*	*O. karongae*
Ripe male color	Black	Blue or white head	Black
Female/juvenile color	Dark Grey	Silver Grey	Brownish (often yellow dorsal margin)
Body shape	Slim, big head	Deep-bodied	Slim, except in Lake Malombe
Jaws	Large	Small-Medium	Small
Teeth	3-4 (5)	3-7 rows	3-14 rows
Pharyngeal toothed area	Small	Medium	Medium-large
Minimum size for accurate identification	15 cm	20 cm	20 cm

Source: Turner *et al.* (1992)

There is a need for a study that can recruit the broodstock of the species and use the morphometric classification (Staff at the Malawi Fisheries Research Institute in Monkey bay have basic knowledge on the classification). Once the species have been classified, there is need to carryout molecular genetics to confirm the morphometric classification. (The biology Department at Chancellor College has equipment for the molecular genetics work). Once identified, the *O. karongae* can be subjected to various research works and the other Chambo species could also be tested for their aquaculture potential.

<u>Nutrition</u>

The Chambo are both phytophagous and zoophagous in diet when in the wild (Mwanyama 1993). This feature makes them switch from one food type to another depending upon abundance and size. When the phytoplankton is in abundance, the Chambo specializes on phytoplankton feeding, preferring the small sized phytoplankton such as melosira. When zooplankton is in abundance, the Chambo switch to zooplankton feeding, preferring the slow moving zooplankton such as copepods and rotifers. This means that pond fertilization is very important in aquaculture.

The Chambo being a tilapia, which generally are optunistic in nature, also feeds on food particles and can ingest food that is artificially supplied. Maldeco has been able to grow the Chambo in cages using artificially formulated feeds in pellet form. Most of the formulated pellets use fishmeal, blood meal, meat and bone meal as a source of protein and these materials are expensive and scarce. There is a need for research into least cost combinations of feed ingredients especially protein sources from materials of plant origin which are less costly. These materials could be used to produce cheaper fish feeds in combination with the animal sources of protein. These plant sources are; soya beans, cottonseed cake, lecaena, groundnut cake and others.

The National Aquaculture Center has the machinery necessary for feed formulation, tanks for growth testing and the supporting laboratories for this research work.

Genetics

Genetic selection has improved the performance of the *Oreochromis niloticus* and has resulted to 60% growth rate and improved feed utilization efficiency (Eknath et al. 1990). The tilapia selective breeding program at the National Aquaculture Centre was initiated in 1996 on *Tilapia rendalli* and *Oreochromis shiranus* and the work is in progress. The *O. shiranus* selection work is at the 3rd generation and that of *T. rendalli* is at the 2nd generation. There has been no genetic improvement program on *O. karongae* until most recently when broodstock recruitment work has commenced. The selection program for *O. karongae* should involve collection of more broodstock from the Shire river, Mangochi, Cape Maclear, Salima, Nkhotakota, Nkhatabay (Kachere and Chiwana beaches) and Karonga. This broodstock should be identified using the methods developed on the biology and taxonomy section. The fish should be bred using single pair matings in concrete tanks and hapas and after estimating the genetic parameters such as heterosis and genetic variance, a base population will be formed from which generations of selection will be done.

The National Aquaculture Center has the tank and pond facilities but there is a need to procure more hapas and tags. There is staff that is already trained on these techniques.

Growth, Reproduction and Sex reversal

Tilapias have been the major cultured species in the world due to their desirable traits, however, one of the most important problem is stunting. With stunting, an individual switches from growth to reproduction at a small size. Research has been conducted to solve the precocious breeding problem in tilapia worldwide and these include; Sex chromosome manipulation, hormonal sex reversal, production of super or YY males and manual hand sexing.

a. Hormonal sex manipulation

This results in the production of triploids or tetraploids. It involves subjecting the developing fish eggs to either a cold or heat shock. The polypoids grow fast but they are sterile and hence there is shortage of seed. This method would make farmers to continuously rely on the government stations to supply them with fingerlings.

b. Sex reversal

Sex reversal techniques are responsible for the thriving tilapia industry worldwide. The technique is based on the fact that males grow faster than females. Sex reversal involves the feeding of the fry during the first 14 days in life, a feed containing the male hormone, testosterone. This results in the production of all-male (above 90% males) population. This technique has not been adopted in Malawi because there is a problem to source the hormones. In addition, the hormones are very expensive to be affordable by farmers. Most people in the west are now reluctant to eat fish that has been sex reversed by hormones, so the market is rather limited for the sex-reversed fish.

c. Production of super males

Through the sex reversal technique, it is possible to mate sex reversed females (XY) and normal males (XY) with the possibility of having a YY chromosome combination in the offspring with a frequency of 0.25%. These YY males produce all males offspring when mated to normal females. This would be a sustained way of improving the growth performance of the Chambo in aquaculture, because once the super males are produced, they can be used for a long time. These males could also be distributed to seed producing farmers so that other farmers could be buying the seed from these producers right there in the villages.

The production of super males would not be a very big problem at the National Aquaculture Center because the facilities were already established under the JICA Aquaculture Project and there is technical staff that is already trained in the techniques.

d. Manual or hand sexing

This involves the growing of tilapia fry scooped from the breeding ponds to 15-20 g and manually sex them by observing the genital area. The males are separated from the females and all male populations are raised separately in ponds. This technique is not accurate because it is prone to human error. Besides, for commercial fish farmers with a large number of ponds, this method is time consuming and hence not practical for commercial fish farmers.

<u>On-farm trials</u>

The on-farm trials involve the carrying out of research in farmers' ponds. It is a very good tool in technology transfer with small-scale fish farmers. However, if commercial aquaculture is being promoted, there is no need to conduct on-farm trials as such, but model farmers and farms could be identified where on-farm demonstration of techniques could be done to the new and would be farmers. The Department can also lease some of its infrastructure to the private sector for joint trials in the aquaculture.

On farm trials constraints.

a. Water availability

With reliance to water from streams and rivers for filling aquaculture ponds and availability of pumps non-existence for smallholder farmers, the demand for water is clearly in excess of availability especially during the dry season. As a result, most of the ponds cannot be harvested by draining completely. This reduces the number of production cycles a farmer can have to less than two a year. This can affect seasonality of conducting on farm trials to the wetter seasons of the year depicting a false impression of the real scenario of fish farming in Malawi.

b. Farmers Satisfaction of On Farm Trials

As trials are conducted with the farmer's participation, the farmers have their own timetable that does not tally with extension workers. This forces the farmers in partly harvesting the fish forcing researchers to collect false data at the end of the trial. This comes as a result that a farmer cannot wait when his family has no food but has a pond with fish until the scheduled date for harvesting.

c. Researcher managed research versus farmer managed research

Most of the on–farm research activities are planned by the researchers with little involvement of the farmers. Farmers are only taken on board during the implementation of the experiments. This has resulted in farmers losing track of the objectives and overall goal of the on-farm research activities.

d. Time/land availability

Most of the fish farmers have either one or two ponds. These farmers are reluctant to put aside some of their land to be put to aquaculture because the suitable land is used for staple crop cultivation. In order to carry out trials, replicates are done at fish farmers located far away and have different sized ponds. To conduct trials using these farmers' ponds', it involves considerable amount of time and trials are usually unsynchronized.

e. Species Preference

Most of the On Farm trials carried out involve *Oreochromis shiranus* and *Tilapia rendalli*. Much research has been conducted using *O. shiranus* which is not preferred to by farmers in terms of poor growth. However the species can recover quickly in times of drought, which frequently occur. The reason is that this species is self sustainable in terms of fingerling source. Farmers show a preference to *T. rendalli*.

f. Open field days

Farmer to farmer contacts is reported to be weak especially to farmers who reside in areas not visited by extension workers. The problem becomes more to those farmers who do not belong to any club. Information of better fish husbandry becomes very limited. When open field days are conducted, it is the extension worker who nominates participating farmers and this selectivity considers those farmers who are doing better in fish farming.

Way forward for undertaking on-farm research

- There is need to carefully analyze the farmer's priority problems, needs and opportunities before an on-farm research is conducted with the farmers.
- There is need to target on-farm research with appropriate technologies which can address the needs of the farmers with their full involvement of the farmers from planning, implementation and evaluation.
- The existing technologies need to be fully appraised by reviewing all the existing data from local experimental stations as well as regional and international research which can be incorporated in the on-farm research.
- The role of NAC in conducting on-farm research should be clearly defined in the context of its capabilities and resources.

Economics and marketing

This area has not been tackled in detail because most of the farmers are small scale where all the production is sold at the pond site. However, with commercial aquaculture where more fish is produced, there is need to establish markets where the fish will be sold. There are several potential markets for aquaculture products which are;

a. Supermarkets

Initial surveys conducted by the National Aquaculture Center show that most supermarkets such as PTC, Shoprite etc, would like to sale aquaculture products in their shops. The problem is that they require a steady and regular supply for example 500 kg/ week, for the whole year. The problem has been that fish production from small scale aquaculture has been too little to satisfy that huge demand.

b. Institutions

Training institutions such as secondary schools, seminaries, teachers' and nurses' training colleges would like to have a regular supply of fish in a given time period such as weekly or monthly. Small scale aquaculture cannot supply this fish, but the market is still there and is not tapped at all.

c. Export

There is a huge domestic demand which is not satisfied with the current supply of fish from both capture fisheries and aquaculture. When this demand is satisfied, the export market could be explored. There are a lot of requests being received by the National Aquaculture Center from neighboring countries such as Zambia, Zimbabwe and South Africa for the export of Chambo to these countries.

d. Economics

The economic issues are cross cutting at each production technology, where the costs of inputs, labor and capital should be considered in relation to the anticipated output.

There is need for the department of fisheries to undertake research in economics and marketing to develop appropriate recommendations for fish farming. This can be done through the preparation of economic analysis at different levels of fish farming enterprises (small to large) and advise farmers accordingly.

This can be done through the collection of data on quantities of physical inputs and outputs, revenue and costs to analyze the prevailing farm and management practices and to indicate the most profitable way of farming under improved circumstances.

3. CONSTRAINTS

Opportunity cost

There is always a conflict on the use of resources for other agricultural activities such as land, labor, water and agricultural wastes which could also be used for the production of other agricultural enterprises. Aquaculturists therefore need to take a careful economic analysis of the benefits of embarking on different enterprises as they relate to fish farming.

Economics of production

While the farmers embark on fish farming there is need to assess the economics of production to determine the optimal production practices for different species at different levels.

Key areas of research

- Production cycles:

At present the department of fisheries recommend a production cycle of is six months but there is need to analyze the potential of shortening or lengthening the production and its economic impact for different species at different levels.

- Production practices:

There is need to economically assess different management practices at different levels for the department to make proper recommendations. Some of the practices which need economic analyses include the polyculture versus monoculture of different species; the use of external inputs versus the use of on-farm inputs.

- Monitoring:

For the aquaculturist to make proper economic analyses of different farms at different levels there is need to train the farmers on how they can monitor their farm activities through proper record keeping.

- Marketing:

Most of the fish in aquaculture is always sold fresh but the prices at which fresh fish is sold is not as competitive as other livestock products. Fish products are relatively cheap yet they have high nutritive value. There is lack of exchange of information on pricing of aquaculture products in different areas.

There is no processing of fish produced in aquaculture for marketing. There is therefore need to conduct research on how aquaculture products can be presented in different forms by processing to add value to the products.

Another mechanism that is required for the efficient marketing of fish is to ensure a

a year-round supply of cultured fish. This calls for a joint research effort of production and its impact on the marketing of such fish.

Development of aquaculture research plan, National Aquaculture Center

(Main fish species: Oreochromis Karongae and Oreochromis Mossambicus Control species: Oreochromis Shiranus and Tilapia Rendalli)

Research Programme	Expected output (Projects)	Research Institution	Time frame	Funding source
1: Information Communication Technology (ICT)	1.1: Information System (Database/Webbased) 1.2: Information reviewed 1.3: Networking 1.4: Publications /Dessemination 1.5: Policy reviewed	1.1.1: NAC, WFC 1.2.1: NAC, WFC 1.3.1: WFC, NAC 1.4.1: WFC NAC 1.5.1: DOF	Jan 2005 - Dec 2007	JICA, WFC, COMPASS, DOF
2: Breeding	2.1: Broodstock selected and managed 2.2: Sex ratios determined 2.3: Stocking densities determined 2.4: Breeding cycles established 2.5: Predation in nursery ponds controlled 2.6: Fry feed determined 2.7: Fry production established 2.8: Hatchery managed 2.9: Genetically improved breeds selected	2.1.1: NAC, FRU,Comm. Farmers 2.2.1: NAC Bunda 2.3.1: NAC, Bunda, Comm. farmers 2.4.1: NAC, Bunda, Comm, farmers 2.5.1: NAC 2.6.1: NAC, Bunda 2.7.1: NAC, Comm farmers, Bunda 2.8.1: NAC Comm farmers 2.9.1: NAC, Chanco, NLH, Bunda	Jan 2005 - Dec 2009 Jan 2005- Dec 2010	JICA, GKL, MALDECO, RPC, DOF, GOM JICA,MAROP, NRCM, USAID (Nature) WFC/UNDP
3: Growth and Production	3.1: Appropriate feeds developed 3.2: Sex reversal technology developed 3.3: Appropriate production systems established	3.1.1: NAC, Bunda, WFC, Comm farms 3.2.1: NAC, Bunda, WFC 3.3.1: NAC, Rhodes, AIT, WFC/USM	Jan 2005 - Dec 2007	JICA, WFC, Comm farms DBSA, USAID, NRCM, RPC, MAROP, DoF/GOM

	3.4: Optimum fish stocking densities established	3.4.1: NAC, Bunda, WFC, Comm farm		
	3.5: Fish production cycles for different markets established	3.5.1: NAC, Bunda, WFC, Comm farm		
4: Sociol-economic and Marketing	4.1: Economic and Financial Analysis of all production technologies carried out 4.2: Fish Market structure, conduct, performance determined 4.3: Fish supply and trends established 4.4: Consumer preferences established 4.5: Fish quality standards established (Processing, value adding, product development) 4.6: Tenure systems for the development of aquaculture defined	4.1.1: DoF/EP&D, Bunda, Chancellor College 4.2.1: Chancellor college, DoF, Bunda 4.3.1: DoF, Bunda, Chanco 4.4.1: DoF, Econ. Dept., WFC, APRU, NSO, 4.5.1: DoF, MBS, WFC 4.6.1: DoF, Bunda, NSO	Jan 2005-Dec 2008	UNDP, NEPAD, FAO, GOM, JICA COMESA, EU,

Attachment 4

Extract from DIAS showing species introduced in Zambia, Mozambique, Tanzania, Malawi and Zimbabwe

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Zambia								
Aspathara wahlbergi	Lake Kariba	1980	Aquaculture	Unknown	No data	No data	Unknown	Unknown
Astatoreochromis alluaudi	Uganda	1979	Snail control	Not established	No data	No data	Unknown	No data
Bagrus meridionalis	Malawi	1971	Fill ecological niche	Not established	No data	No data	Unknown	No data
Boulengerochromis microlepis	Tazania (Lake Tanganyika)	1989	Aquaculture	Probably not established	No data	No data	Unknown	Unknown
Cherax albidus	South Africa	1992	Aquaculture	Probably not established	No data	rarely used	Unknown	No data
Cherax quadricarinatus	South Africa	1992	Aquaculture	Probably not established	No data	rarely used	Unknown	No data
Ctenopharyngodon idellus	Israel, Mauritus	1980s	Aquaculture	Not established	No data	No data	Unknown	No data
Cyprinus carpio carpio	South Africa, Malawi, Israel	1946	Aquaculture	Not established	No data	Widely used	Unknown	Probably some
Gambusia affinis affinis	South Africa	1940s	Mosquito control	Not established	No data	No data	Unknown	No data
Hypophthalmichthys molitrix	Unknown	Unknown	Aquaculture	Unknown	No data	No data	Unknown	No data
Lepomis cyanellus	USA	Unknown	Aquaculture	Probably established	Natural reproduction	No data	Unknown	Unknown
Lepomis macrochirus	USA	1946	Aquaculture	Not established	No data	No data	Unknown	Unknown
Limnothrissa miodon	Tazania (Lake Tanganyika)	1992	Fisheries	Unknown	No data	No data	Unknown	Unknown

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Limnothrissa miodon	Tanzania/Zaire	1967-1968	Fisheries and fill ecological niche	Established	Natural reproduction	No data	Unknown	Some
Micropterus dolomieu	South Africa	1947	Aquaculture	Probably not established	No data	No data	Unknown	No data
Micropterus punctulatus	South Africa	1945	Unknown	Not established	No data	No data	Unknown	No data
Oncorhynchus mykiss	South Africa	1942	Unknown	Not established	No data	No data	Unknown	No data
Oreochromis aureus	Israel/Scotland	1980s	Aquaculture	Probably established	No data	No data	Unknown	No data
Oreochromis mortimeri	Zimbabwe	1991	Unknown	Unknown	No data	No data	Unknown	No data
Oreochromis niloticus niloticus	Germany	1991	Unknown	Unknown	No data	No data	Unknown	No data
Oreochromis niloticus niloticus	Scotland	1983	Unknown	Established	Natural reproduction	No data	Unknown	No data
Poecilia reticulata	Unknown	Unknown	Unknown	Established	No data	No data	Unknown	No data
Procambarus clarkii	Kenya	1978	Aquaculture	Probably not established	No data	Rarely used	Unknown	No data
Serranochromis robustus robustus	Zaire (probably Lake Chilanga)	1980s	Unknown	Unknown	No data	No data	Unknown	No data
Tilapia rendalli	Zaire	1948	Unknown	Established	No data	No data	Unknown	No data
Tinca tinca	USA	1946	Snail control	Not established	No data	No data	Unknown	No data
Xiphophorus hellerii	Unknown	Unknown	Ornamental	Unknown	No data	No data	Unknown	No data
Mozambique								
Ctenopharyngodon idellus	Cuba	1991	Aquaculture and Fisheries	Not established	No data	Rarely used	None	Probably none
Cyprinus carpio	South Africa	Unknown	Diffused from other countries	Unknown	No data	No data	Unknown	No data

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Hypophthalmichthys molitrix	Cuba	1991	Aquaculture and Fisheries	Not established	No data	Rarely used	None	Probably none
Hypophthalmichthys nobilis	Cuba	1991	Aquaculture and Fisheries	Not established	No data	Rarely used	None	Probably none
Limnothrissa miodon	Tanzania	1970s	Diffused from other countries	Established	No data	No data	Unknown	No data
Micropterus salmoides	Swaziland	1947	Angling/ Sport	Unknown	No data	No data	Unknown	No data
Oncorhynchus mykiss	Zimbabwe	Unknown	Unknown	Unknown	No data	No data	Unknown	No data
Oreochromis niloticus	Unknown	Unknown	Aquaculture	Unknown	No data	No data	Unknown	Probably some
Oreochromis spilurus	Unknown	Unknown	Unknown	Unknown	No data	No data	Unknown	No data
Perna perna	Unknown	1970s-80s	Aquaculture	Unknown	No data	No data	Unknown	No data
Tanzania								
Ctenopharyngodon idellus	India	1981	Aquaculture	Not established	No data	No data	Unknown	Probably none
Cyprinus carpio	Unknown	Unknown	Aquaculture	Unknown	No data	No data	Unknown	No data
Hypophthalmichthys molitrix	India	1981	Aquaculture	Not established	No data	No data	Unknown	No data
Lates niloticus	Uganda	1954	Fill ecological niche	Established	Natural reproduction	No data	Some	Some
Oncorhynchus mykiss	Scotland	1927	Angling/ Sport	Probably established	Natural reproduction	No data	Unknown	No data
Oreochromis andersonii	Zambia	1968	Aquaculture	Established	Natural reproduction	Rarely used	Unknown	No data
Oreochromis esculentus	Lake Victoria	1950s	Fill ecological niche	Established	Natural reproduction	No data	Unknown	No data

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Oreochromis leucostictus	Lake Albert	1954	Unknown	Established	Natural reproduction	No data	Unknown	No data
Oreochromis niloticus niloticus	Unknown	1950s-60s	Fisheries	Established	Natural reproduction	Widely used	Some	Some
Tilapia rendalli	Unknown	1962	Aquaculture	Established	Natural reproduction	No data	Unknown	No data
Tilapia sparrmanii	Unknown	Unknown	Unknown	Probably not established	No data	No data	Unknown	No data
Tilapia zillii	Unknown	1965	Aquaculture	Established	Natural reproduction	No data	Unknown	No data
Malawi								
Ctenopharyngodon idellus	Israel	1976	Aquaculture	Not established	No data	No data	Unknown	Probably none
Cyprinus carpio	Israel	1970	Aquaculture	Not established	No data	Rarely used	Probably some	Probably some
Hypophthalmichthys molitrix	Israel	1970	Aquaculture	Not established	No data	No data	Unknown	No data
Lepomis macrochirus	Unknown	Unknown	Forage and angling/sport	Probably established	Natural reproduction	No data	Probably none	Unknown
Micropterus salmoides	Zimbabwe	Unknown	Angling/ Sport	Established	Natural reproduction	No data	Probably some	Probably some
Oncorhynchus mykiss	England	1906	Angling/ Sport	Established	Natural reproduction	No data	Probably some	Probably some
Phalloceros caudimaculatus	Unknown	1951	Mosquito control	Established	Natural reproduction	No data	Probably some	Unknown
Phalloceros caudimaculatus	Brazil	1956	Mosquito control	Established	Natural reproduction	No data	No data	Unknown
Poecilia reticulata	Unknown	1984	Accidental	Probably not established	No data	No data	Probably some	Probably some

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Salmo trutta trutta	England/South Africa	1906	Angling/ Sport	Probably not established	No data	No data	Unknown	Unknown
Zimbabwe								
Bagrus meridionalis	Malawi	1971	Fill ecological niche	Probably not established	No data	No data	Unknown	No data
Barbus aeneus	South Africa	1927	Angling/ Sport	Probably not established	No data	No data	Unknown	Unknown
Barbus kimberleyensis	South Africa	1928	Angling/ Sport	Not established	No data	No data	Unknown	No data
Barbus natalensis	South Africa	1960	Angling/ Sport	Not established	No data	No data	Unknown	No data
Carassius auratus	Unknown	Unknown	Unknown	Established	Natural reproduction	No data	Unknown	No data
Catla catla	India	1966	Unknown	Probably not established	No data	No data	Unknown	No data
Cirrhinus mrigala	India	1966	Aquaculture	Not established	No data	No data	Unknown	No data
Ctenopharyngodon idellus	Unknown	1995	Weed control	Not established	No data	No data	Unknown	No data
Cyprinus carpio carpio	South Africa	1925	Aquaculture	Probably established	Natural reproduction	Rarely used	Unknown	Unknown
Gambusia affinis affinis	USA	1925	Mosquito control	Established	Natural reproduction	No data	Unknown	No data
Hypophthalmichthys molitrix	Unknown	Unknown	Aquaculture	Unknown	No data	No data	Unknown	Probably some
Labeo rohita	India	1965		Not established	No data	No data	Unknown	Unknown
Lepomis cyanellus	South Africa	1940	Forage	Not established	No data	No data	Unknown	Unknown

Species	Introduced from	Year Introduced	Reason	Established in the wild	Established through	Use for Aquaculture	Ecological impact	Socio economic impact
Lepomis macrochirus	USA	1940	Forage	Established	Natural reproduction	No data	Unknown	Unknown
Limnocaridina tanganicae	Tazania (Lake Tanganyika)	1967 / 68	Forage	Unknown	No data	No data	Unknown	Unknown
Limnothrissa miodon	Tazania (Lake Tanganyika)	1967 / 68	Fill ecological niche	Established	Natural reproduction	No data	Unknown	Some
Macrobrachium rosenbergii	Unknown	1980	Aquaculture	Probably not established	No data	No data	Unknown	Unknown
Micropterus dolomieu	South Africa	1942	Angling/ Sport	Not established	Continuous restocking	No data	Unknown	No data
Micropterus punctulatus	South Africa	1945	Angling/ Sport	Established	Natural reproduction	No data	Unknown	No data
Micropterus salmoides	South Africa	1932	Angling/ Sport	Established	Natural reproduction	No data	Unknown	No data
Oncorhynchus mykiss	South Africa	1910	Angling/ Sport	Established	Natural reproduction	No data	Unknown	No data
Oreochromis aureus	Unknown	Unknown	Aquaculture	Unknown	No data	Widely used	Unknown	Probably some
Oreochromis niloticus	Scotland, Kenya	1986	Aquaculture	Probably not established	No data	Widely used	Some	Probably some
Oreochromis niloticus niloticus	Kenya	1990	Unknown	Unknown	No data	No data	Unknown	No data
Procambarus spp	Unknown	Unknown	Aquaculture	Unknown	No data	No data	Unknown	No data
Salmo trutta trutta	South Africa	1927	Angling/ Sport	Established	Natural reproduction	No data	Unknown	No data
Salvelinus fontinalis	South Africa	1955	Unknown	Established	Natural reproduction	No data	Unknown	No data
Tinca tinca	South Africa	1920	Angling/ Sport	Established	Natural reproduction	No data	Unknown	No data

ADiM Working Paper 7

Literature Review on Research and Development of Mozambique Tilapia (*Oreochromis mossambicus*)

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Literature Review on Research and Development of Mozambique Tilapia (*Oreochromis mossambicus*)

Contents

Attachment

1. Introduction

Tilapia culture is one of the most rapidly growing components in aquaculture, and it is a major component of global food fish production. Tilapia production contributes about 5 percent of the total farmed freshwater fish (in 2001 about 6 percent); it is second only to the group of carps. More than 90 percent of tilapia production is outside their native range (Africa). The Nile tilapia, *Oreochromis niloticus*, is the predominant species of all the tilapia grown (it represented about 1,109,412 tons (80%) of total tilapia & other cichlids in 2001); the Mozambique tilapia, Oreochromis mossambicus, accounted for a mere 4 percent (59,294 tons).

2. Why the tilapias?

Tilapias are one of the most widely introduced species groups and they are cultured worldwide in about 70 countries, being exotic everywhere outside of Africa and the adjacent middle-east.

Tilapia is the common name applied to three genera and species of fish in the family Cichlidae: Oreochromis, Sarotherodon, and Tilapia. Tilapia species that refer to three genera and species of fish in the family Cichlidae: Oreochromis, Sarotherodon, and Tilapia, are native to Africa and the Middle East, and these species have been distributed throughout the world and have become the second most important food species in the world. The species that are most important to aquaculture are in the genus Oreochromis, including the Nile tilapia, *O. niloticus*, the Mozambique tilapia, *O. mossambicus*, and the blue tilapia, O. aureus.

Tilapias have a range of attributes that are suited for aquaculture; they have white flesh meat and widely accepted as food fish, their consumption is not restricted by religious observances. They breed freely in captivity without the need for hormonal induction of spawning; most are mouth brooders and provide a high level of parental care; eggs are large and produce large fry that are hardy and omnivorous at first feeding. They reach sexual maturity in less than 6 months which is advantageous for selective breeding; they tolerate a wide range of environmental conditions including low dissolved oxygen levels.

In summary the fundamental advantages of tilapia for aquaculture are:

- feed on a low trophic level;
- members of genus Oreochromis are all omnivores (feeding on algae, aquatic;
- plants, small invertebrates, detritus, etc.;
- relatively inexpensive to feed;
- suitable for rearing under extensive and semi-intensive conditions;
- as omnivore, able to grow on lower protein levels and tolerate higher carbohydrate;
- under intensive systems, can be fed a prepared feed that includes a high percentage of plant proteins;
- relatively disease resistant.

In view of the above advantages, although tilapia are relatively simple to cultivate, resistant to poor water quality and diseases, and able to efficiently convert many organic animal and agricultural waste materials into high quality protein, these advantages are offset by excessive reproduction in culture ponds.

The hope that tilapia culture would make a significant contribution to protein production soon turned to disillusionment, especially in Africa, as the problems associated with its husbandry became apparent.

3. History of Mozambique tilapia (*Oreochromis mossambicus*)

Mozambique tilapia is distributed naturally in Lower Zambezi, Lower Shire and coastal plains from Zambezi delta to Algoa Bay. Country-wise it is endemic (native) to Lesotho, Malawi, Mozambique, South Africa, Swaziland and Zimbabwe. In Malawi it is restricted to the southern part of Malawi (Lower Shire); fairly common in Chikwawa and Lower Mwanza River.

In early years, Mozambique tilapia was a widely sought after fish for culture. It was distributed widely in the tropics and was promoted as food fish for farming, and being exotic it was regarded as a high-priced fish. It had escaped and established itself in the wild in many countries, often competing with local species. It was also stocked in reservoirs to supplement capture fisheries in the 1950s and 1960s in India and Sri Lanka, and actually improved the local fisheries.

During the 1960s and 1970s many efforts were spent in many countries at developing the tilapia culture industry with *O. mossambicus,* as means for improving the nutrition of the rural poor. However, the Mozambique tilapia was poorly accepted and commercial culture never materialized for a number of reasons, such as muddy taste and dark colour of these fish discouraged customers, uncontrolled reproduction and mixed sex culture resulted in numerous stunted and unmarketable fish. Furthermore, it was also raised concern about possible negative impacts of the Mozambique tilapia on native fish fauna and on the freshwater capture fishery. All these cumulated to resistance by prospective commercial fish producers. Currently, this species is not considered for large-scale culture. In 2001, Mozambique tilapia contributed a mere 4% (59,294 tons) of tilapia aquaculture total of 1,385,223; of which about 80% or 1,109,412 tons were Nile tilapia.

Nevertheless, it had played considerable role in aquaculture in few countries prior to introduction of Nile tilapia; particularly in the Philippines, Indonesia, Malaysia, India and Sri Lanka. When cultured in ponds and due to lack of culture technology, excessive reproduction became uncontrollable resulting in low economic return for those in the culture business. The poor performance of *O. mossambicus* in aquaculture in most Asian countries was also attributed to a small number of original strains/stocks and lack of stock management that led to loss of genetic diversity and inbreeding. As a result, the Asian strains of *O. mossambicus* are known to be genetically depauperate. A species shift in aquaculture occurred in the 1960s to a better domesticated and faster growing North African tilapia *O. niloticus* (Nile tilapia) which displaced *O. mossambicus* from the majority of aquaculture. For example, the Nile tilapia is now the most important freshwater fish in the Philippines; it essentially replaced the culture of Mozambique tilapia. Nile tilapia became a much sought after fish by aquaculture farmers worldwide. The tilapia farming, especially Nile tilapia has progressed (Nile tilapia has taken the lead as the principal species for aquaculture needs) tremendously with further developments of the sex-reversed tilapia and mono-sex culture, the genetically improved tilapia, improvement of culture techniques, the genetically enhanced tilapia, and (with the GIFT program and the YY-male technology to produce Genetically All-Male Tilapia (GMT)

4. Aquaculture of *O. mossambicus* in Southern Africa

It is generally said that there is a significant potential for aquaculture in Africa at various different levels from intensive commercial production to more extensive, low-input and subsistence production with available and underexploited or unexploited resources. Past attempts (except in some isolated cases) at aquaculture development have met limited success either due to limited resources and/or the extension of inappropriate or unsustainable aquaculture technologies and practices.

O. niloticus as the main aquaculture species has not penetrated widely and intensively in Africa with the exception of Egypt, although to some extent being cultured in some countries namely, Zambia, Zimbabwe, Tanzania, etc. Nile tilapia is not endemic in many African countries, and one of the constraints to the development in Southern Africa is the risks associated with its introduction; for example evidence in Lake Victoria the eventual disappearance of weaker species, indicating the Nile tilapia is the more aggressive species.

Conversely, *O. mossambicus*, existing in their native range in Southern Africa, has seldom been considered as an aquaculture species to play a role in aquaculture development. Early attempts with this species were hampered by technical and environmental factors; one of the main obstacles was the prolific breeding achieved through precocious maturity (high fecundity) leading to the production of small fish (greater tendency to stunting) of little market value. In addition, its poor performance as an aquaculture species in most Asian countries is also not attractive to aquaculture.

However, *O. mossambicus* has its admirers who have not given up in their attempt to adopt this species in aquaculture. Supposedly, undisturbed wild populations of *O. mossambicus* tilapia are known to still exist in their native range in Southern Africa, and these wild *O. mossambicus* from Southern Africa can serve as a source of genetic material for developing and supplementing new aquaculture strains. The growth performance and appearance of wild *O. mossambicus* in Southern Africa were quoted as being superior to those introduced in Asia. Therefore, *O. mossambicus* did receive some interest for aquaculture in Southern Africa due to its favorable growth compared to other indigenous tilapia species in the region.

5. Suitable fish species for aquaculture in Malawi

The suitable indigenous tilapia fish species for aquaculture in Malawi are *O. shiranus*, *O. karongae*, *T. rendalli*, and given the research that has been undertaken for these species, it is really uncertain whether commercial fish farming or aquaculture can be developed with *O. shiranus* and *T. rendalli* when one sees the results of trials carried out in Malawi so far. Nevertheless, the Chambo, *O. karongae*, a native and endemic only in Malawi, is currently a candidate for commercial aquaculture; an attempt is being made to culture in cages in Lake Malawi. Its direction to commercial venture or success is yet to be seen.

The Nile tilapia (*Oreochromis niloticus*) is an ideal choice species for aquaculture. It is undoubtedly a much sought after fish for fish farming; it has been introduced in the neighbouring countries, Zambia, Tanzania, Mozambique and Zimbabwe, and successfully cultured and marketed. Much interest has been shown by some prospective fish farmers to use Nile tilapia for fish farming. However, it is not a candidate to be considered in Malawi in view of the legal ban on the import or introduction of exotic fish species and to preserve and conserve the country’s priceless aquatic biodiversity. A consensus was also reached at a regional workshop held in August of 2004 that

Malawi should once again take a look more closely to the true potential of the existing fish species, especially *Oreochromis mossambicus*, and to observe the legal ban on alien species.

Under this circumstance, Mozambique tilapia, *O. mossambicus*, is an ideal choice fish species for fish farming which is native in Malawi; it occurs naturally in the Shire River in the south, and is not seen to play any role in fish farming. But it does contribute substantially to capture fishery production. A question was raised at a regional workshop conducted in August 2004, why this particular fish is not considered for fish farming in Malawi? Mozambique tilapia is a domesticated fish and was widely cultured in many countries prior to the use of Nile tilapia, for fish farming. Mozambique tilapia has the following advantages:

- Mozambique tilapia has exhibited or shown to be a candidate for commercial fish farming in other countries, to name a few countries, namely, Indonesia, Philippines, Thailand, Malaysia, India, etc. Therefore, there are quality wild broodstocks and fingerlings, production system, husbandry, feed, and relevant practices that could be considered and easily adapted to Malawi.
- Use of Mozambique tilapia (a native in Malawi as well as in Southern Africa) will avoid or will not invite any public outcry or opposition from international scientists and donors in view of their concern for conservation for the biodiversity of Lake Malawi and other water bodies.
- Use of Mozambique tilapia will be in line with the adapted “Nairobi Declaration” by SADC countries as a basis for formulating strategies and policy for sustainable development of indigenous aquatic resources.

In fact in the 1980s, attempts were made to demonstrate of commercial viability of native strains as well as imported strains of Mozambique tilapia in polyculture with grass carp and silver carp at Kasinthula Fisheries Experimental Station (Chikwawa-Lower Shire region). The growth rate was slow and no further attempt was made seriously.

In view of the research and development on the Mozambique tilapia since then or in recent years, an attempt on introducing the species for small-scale commercial aquaculture in a designated area (Lower Shire) is recommended. In this context, a review of the R&D of the species is presented here for the attention or perusal by relevant agencies and authorities

6. Review of Information on *Oreochromis mossambicus*

6.1 Purpose of the Review

This review is undertaken in line with the recommendation at the regional workshop to look into the possibility of using Mozambique tilapia in fish farming. Additionally this review would save time and limited resources at disposal to relevant institutions in Malawi; otherwise it has to render substantial resources and personnel to conduct a program of applied research and investigations on the Mozambique tilapia. Therefore, this review is an attempt to collect and compile the data and information available on the species.

Leading international journals on aquaculture and fisheries were consulted and reviewed for information on genetics, improved strains, pond management, production system, feed, etc. The list of publications on *Oreochromis mossambicus* in the recent bibliography published by World Fish Center (Attachment-4) is also browsed through to identify articles that could be sourced for this report.

6.2 Review Result

Abstracts of the relevant articles, not the full texts, are compiled in this report (Attacment-1). The sources or references of the articles are included in case the user needs to access the full texts. The information included here may not be of much use now in Malawi under current circumstance; but it hoped that some of them could be easily adopted and applied in Malawi.

A considerable work has been done on Nile tilapia and its improved strains (GIFT super tilapia) rather than on Mozambique tilapia. Therefore, with the Nile tilapia in the lime light due to its good growth performance and other attributes, Mozambique tilapia has lost its charm among commercial fish farmers. The research works on this species is more or less focused on pure research whose application could be elsewhere rather than directly for commercial aquaculture in Malawi. The information sought here is on the production systems, growth performance and improved strains that could be easily adapted to the Malawian scene.

Nevertheless, due to commercial interest or secrecy, data and information on the rearing temperatures, site-specific conditions including the genetic growth potential of the strain, dietary influences, culture conditions, etc., with reference to the Mozambique tilapia could be closely guarded and not distributed by commercial fish farmers. Like in any industry including commercial farming of Nile tilapia, it could be that commercial operators are reluctant and unwilling to share with others; therefore, they are not published in leading and popular scientific journals. Nonetheless, it could have been reported in newsletters of commercial farmers association or clubs and so on and circulated among the members.

6.3 Present status of *O. mossambicus* in fish farming/aquaculture

In spite of paradigm shift in tilapia farming to Nile tilapia, there is a growing body of supporters or sympathizers to Mozambique tilapia, which was once a pioneer species in fish farming and fisheries (Attachment-3). The general opinion is this species has never been properly evaluated or put to trial evaluations of growth performance in wild species neither under commercial conditions nor on a small-scale (homestead ponds) subsistence level.

A case in point is a project conducted with wild strains of *O. mossambicus* in its native range namely Southern Malawi, South Africa, and Mozambique from December 1998 to June 2002. This project was implemented under the DFID Aquaculture and Fish Genetics Programme, with an overall purpose was to develop a higher yielding genetically male tilapia (GMT) for improved livelihoods in small-scale aquaculture in Southern Africa. It was a collaborative research activity between the University of Stellenbosch in the Western Cape Province of South Africa and the University of Wales Swansea in UK. For more detail, please refer "Genetic Improvement and Utilization of Indigenous Tilapia in Southern Africa" – a DFID Aquaculture and Fish Genetics Programme (R 7284) by D. Brink, G.C. Mair, L. Hoffman and J.A. Beardmore.

The project had the following specific project research objectives.

- To develop as assembly of accession of up to 15 strains of *O. mossambicus* from throughout Southern Africa; to conduct growth trials for a minimum of eight strains under communal stocking in two environments to include farm cages and earthen ponds to determine the relative culture performance of the strains.
- To undertake genetic characterization of available strains of *O. mossambicus* using molecular techniques; strains are to be characterized for strain specific markers, levels of genetic variability and population structure.
- Adaptation of the YY male technology to strains of *O. mossambicus* chosen on the basis of growth data and species purity, and development of GMT (genetically male tilapia).
- On-farm trials of GMT are to be conducted in the final year of the Project in both cages and ponds. Comparisons are to be made with non-improved, locally available *O. mossambicus* as controls.
- The research output highlights are briefly provided below.
- 12 populations of *O. mossambicus* were assembled their accessions maintained and reared through several cycles in capacity; these strains are being maintained as a live gene bank at the University of Stellenbosch. Among the 12 populations, two were from locations at Kasinthula and Sucoma in Lower Shire (Malawi).
- Excellent broodstock conditioning, egg incubation and nursery facilities have been developed for tilapia breeding and for conduct of various types of genetic work
- Relative growth performance of 10 of the *O. mossambicus* accessions was characterized through different phases of the life cycle. Four strains identified having superior growth performance; these four strains are recommended to form the basis of future breeding programmes for the improvement of the species. Three of these faster growing strains were incorporated into the programme for YY-male production and were bred to provide fingerlings for field trials and pilot projects. Among the faster-growing strains, the Kasinthula strain was one of them that was consistently fastest growing at all stages of the culture cycle.
- Transfer of YY technology from *O. niloticus* to *O. mossambicus* had been relatively successful at all stages of application.
- Transfer of molecular technology from *O. niloticus* to *O. mossambicus* had also been proved to be highly successful.
- A series of pilot studies implemented to evaluate the potential and impact of tilapia aquaculture as a component of rural development projects with the Western Cape Department of Agriculture as a research partner.

A summary of the on-farm trials/pilot studies of the GMT (*O. mossambicus*) under different operating conditions is listed below.

Table 6.1 Fish categories discussed in this report and their associated species groups

Location	Operating System	Data
Leliefontein, Namakwaland Northern Cape Province	Open water system, irrigation dam	15,000 fingerlings were stocked in October 2000; fish in a size range of 180 to 400 g harvested in March 2001
Matjiesrivier, Oudshoorn, South Western Cape	Pond systems, 4 x 600 m3	6000 fingerlings (15 g) were stocked in Sept. 2000; pond fertilization with supplementary feeding at latter stages; fish in a size range of 250 to 450 g harvested in March to May 2001. A total harvest of 1,830 kg recorded.
Elsenburg, Stellenbosch, Western Cape	Pond systems, 10 x 250 m2	1200 fingerlings (2g) were stocked in October 2000; pond fertilization with supplementary feeding of commercial from early stages (>5g); fish in a size range of 160 to 380 g harvested in March to May 2001. A total harvest of 2,130 kg recorded.
Worcester, Western Cape	Cage farming, irrigation dam (2 x 400 m3 cages)	4000 fingerlings (20g) were stocked in October 2000; fed with artificial feeds; fish in a size range of 230 to 420 g harvested during March to May 2001. A total harvest of 1,460 kg recorded.
Elsenburg, Stellenbosch, Western Cape	Cage farming, irrigation dam (2 x 400 m3 cages)	4000 fingerlings (18g) were stocked in October 2000; fed with artificial feeds; fish in a size range of 200 to 470 g harvested during March to May 2001. A total harvest of 1,350 kg recorded.
Elsenburg, Stellenbosch, Western Cape	Pond systems, 10 x 250 m2	1200 fingerlings (2g) were stocked in October 2000; pond fertilization with supplementary feeding of commercial from early stages (>5g); fish in a size range of 160 to 380 g harvested in March to May 2001. A total harvest of 2,130 kg recorded.

6.4 Where to Procure Improved Strains of *O mossambicus*?

Fishgen Ltd. (the University of Wales, Swansea) A British company established in 1996 and based at the University of Wales Swansea (UWS). The company has the objective of commercializing and promoting technologies and products developed under research programmes on genetic improvement of fish species for aquaculture worldwide. Its mandate is to promote these technologies and to generate income for funding further research.

Fishgen is bringing to the market place the outputs of more than 16 years of active research in fish genetics, particularly with the freshwater tropical fish, the tilapia. At present Fishgen's main product is "supermale" broodstock for the production of monosex male tilapia known as Genetically Male Tilapia (GMT®). GMT® address the problem of early sexual maturation, poor growth of females and unwanted reproduction that plagues the culture of normal, mixed-sex tilapia, significantly enhancing yields from aquaculture production.

GMT® has grown out of the research carried out by scientists at the University of Wales Swansea (UWS) and its collaborators, including the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU), in the Philippines. The majority of this research has been carried out under funding from the British Department for International Development - DFID's Fish Genetics Programme managed by UWS (1990 - 2001).

Fishgen has produced YY males in two strains of wild caught *O. mossambicus* (known as the black tilapia) in South Africa. These *O. mossambicus* seem to have considerably more genetic variance those used in aquaculture today and are anticipated to have much superior growth rates to current aquaculture stocks of this species. For further information to procures supply of the strains, please contact :

Mr. Eric Roderick (UWS)
Fishgen Ltd.
Rom 19, NSBW
University of Wales Swansea
Singleton Park
SWANSEA SA2 8PP
United Kingdom
Tel.: (44) (0) 1792 295382
Fax.: (44) (0) 1792 513030
Email: E.E.Roderick@swansea.ac.uk

7. Bibliography on *Oreochromis mossambicus* (World Fish Center)

A considerable enthusiasm and research efforts have been given to tilapias, as they have become as the second most important fish produced in aquaculture after the carps, their importance as a source of protein for the poor people from developing countries and globally traded commodity recently.

The WorldFish Center library has been acquiring documentation on the subject as part of its efforts to serve the information needs of its staff as well as other external users worldwide. Such documentation ranges from published/unpublished documents, theses, journal articles, to reports and conference papers. The latest bibliography is entitled "A Selected Bibliography on Tilapia (Pisces: Cichlidae)" published in 2003 based on a list of documents available in the WorldFish Center Library. From this selected bibliography, a bibliographic list on *Oreochromis mossambicus* was extracted and compiled here as shown in Annex-4.

Attachment

Attachment 1

List of Abstracts

(A) Aquaculture

1. **Farmed tilapia *Oreochromis mossambicus* involved in transport and biouptake of arsenic in aquacultural ecosystems**
   Aquaculture, Volume 242, Issues 1-4, 20 December 2004, Pages 365-380
   Bo-Ching Chen and Chung-Min Liao
2. **Genetic diversity in farmed Asian Nile and red hybrid tilapia stocks evaluated from microsatellite and mitochondrial DNA analysis**
   Aquaculture, Volume 236, Issues 1-4, 14 June 2004, Pages 131-150
   Maria Rowena R. Romana-Eguia, Minoru Ikeda, Zubaida U. Basiao and Nobuhiko Taniguchi
3. **Effects of bamboo substrate and supplemental feeding on growth and production of hybrid red tilapia fingerlings (*Oreochromis mossambicus*×*Oreochromis niloticus*)**
   Aquaculture, Volume 235, Issues 1-4, 1 June 2004, Pages 303-314
   P. Keshavanath, B. Gangadhar, T. J. Ramesh, A. A. van Dam, M. C. M. Beveridge and M. C. J. Verdegem
4. **Cloning, tissue distribution and hormonal regulation of stearoyl-CoA desaturase in tilapia, *Oreochromis mossambicus***
   Aquaculture, Volume 230, Issues 1-4, 16 February 2004, Pages 527-546
   S. L. Hsieh, H. T. Chang, C. H. Wu and C. M. Kuo
5. **Detection of a chromosomal region with two quantitative trait loci, affecting cold tolerance and fish size, in an F_2 tilapia hybrid**
   Aquaculture, Volume 223, Issues 1-4, 2 June 2003, Pages 117-128
   Avner Cnaani, Eric M. Hallerman, Micha Ron, Joel I. Weller, Margarita Indelman, Yechezkel Kashi, Graham A. E. Gall and Gideon Hulata
6. **An investigation of sex determination in the Mozambique tilapia, *Oreochromis mossambicus*, using synaptonemal complex analysis, FISH, sex reversal and gynogenesis**
   Aquaculture, Volume 221, Issues 1-4, 1 May 2003, Pages 125-140
   Rafael Campos-Ramos, Simon C. Harvey, Brendan J. McAndrew and David J. Penman
7. **Recombinant bovine growth hormone treatment of tilapia: growth response, metabolic clearance, receptor binding and immunoglobulin production**
   Aquaculture, Volume 207, Issues 3-4, 24 May 2002, Pages 359-380
   Thomas A. Leedom, Katsuhisa Uchida, Takashi Yada, N. Harold Richman, III , John C. Byatt, Robert J. Collier, Tetsuya Hirano and E. Gordon Grau
8. **An evaluation of co-extruded poultry silage and culled jewel sweet potatoes as a feed ingredient for hybrid Tilapia (*Oreochromis niloticus*×*O. mossambicus*)**
   Aquaculture, Volume 198, Issues 3-4, 2 July 2001, Pages 269-280
   T. F. Middleton, P. R. Ferket, L. C. Boyd, H. V. Daniels and M. L. Gallagher
9. **Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects**
   Aquaculture, Volume 197, Issues 1-4, 1 June 2001, Pages 283-301
   J.A. Beardmore, G.C. Mair and R.I. Lewis
10. **Compensatory growth in hybrid tilapia, *Oreochromis mossambicus*×*O. niloticus*, reared in seawater**
    Aquaculture, Volume 189, Issues 1-2, 25 September 2000, Pages 101-108
    Yan Wang, Yibo Cui, Yunxia Yang and Fasheng Cai
11. **Breeding new strains of tilapia: development of an artificial center of origin and linkage map based on AFLP and microsatellite loci**
    Aquaculture, Volume 185, Issues 1-2, 2 May 2000, Pages 43-56

Jeremy J. Agresti, Shingo Seki, Avner Cnaani, Supawadee Poompuang, Eric M. Hallerman, Nakdimon Umiel, Gideon Hulata, Graham A. E. Gall and Bernie May

12. **Expression of recombinant tilapia insulin-like growth factor-I and stimulation of juvenile tilapia growth by injection of recombinant IGFs polypeptides** •
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Jyh-Yih Chen, Jian-Chyi Chen, Chi-Yao Chang, Shih-Chieh Shen, Meng-Shu Chen and Jen-Leih Wu

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15. **Experimental studies on polyculture in closed shrimp ponds: I. Intensive polyculture of Chinese shrimp (*Penaeus chinensis*) with tilapia hybrids**
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Aquaculture, Volume 150, Issues 1-2, 15 April 1997, Pages 11-24
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23. **Retardation of ovarian growth and depression of serum steroid levels in the tilapia, *Oreochromis mossambicus*, by cortisol implantation**
Aquaculture, Volume 115, Issues 1-2, 15 August 1993, Pages 133-143
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24. **Serum cortisol response to handling stress and the effect of cortisol implantation on testosterone level in the tilapia, *Oreochromis mossambicus***
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Attachment 2

Fact Sheet on Oreochromis mossambicus

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Farmed tilapia *Oreochromis mossambicus* involved in transport and biouptake of arsenic in aquacultural ecosystems

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Abstract

The present study couples the Michaelis–Menten (M–M) type flux and the Fick's type of dynamic mass transfer flux to arrive at the Best equation to quantitatively model the transport and biouptake mechanism of the gills of freshwater tilapia (*Oreochromis mossambicus*) exposed to waterborne arsenic (As). We conducted a 15-day uptake/depuration bioassay to examine the accumulation kinetics of As in tilapia gills by incorporating a bioconcentration model to obtain the steady-state and dynamic bioconcentration factors. A diffusion-based permeability can be calculated using the physiological and allometric-related parameters. The bioaffinity parameter and the limiting uptake flux in M–M equation are acquired by fitting the experimental values from published literature. The biouptake rate incorporating with bioavailability number is examined to better understand the effects of variabilities of field circumstances on biouptake flux. A linear relationship between As biouptake rate and As concentration in ambient water is obtained. The fitted bioaffinity parameter and limiting uptake flux were 3.07 mg l^{-1} and 2.17 mg l^{-1} day^{-1}, respectively, suggesting a low As binding affinity of tilapia gills yet a relative high binding capacity was obtained. The As permeability through tilapia gills membrane decreased from 1.42 μm day^{-1} to a steady-state value of 0.82 μm day^{-1} after 2 months, indicating the nonequilibrium aspects of biouptake processes involved.

Keywords: Tilapia; Arsenic; Biouptake; Bioavailability

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Genetic diversity in farmed Asian Nile and red hybrid tilapia stocks evaluated from microsatellite and mitochondrial DNA analysis

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Abstract

We analyzed microsatellite and mitochondrial DNA restriction fragment length polymorphism (mtDNA-RFLP) in two domesticated (NIFI and Israel) and four genetically improved (GIFT, GMT, FAC-selected and SEAFDEC-selected) Nile tilapia (*Oreochromis niloticus*) as well as five red hybrid tilapia (*Oreochromis mossambicus*×*O. niloticus*) stocks (BFS, FACred, NIFIred, HL, and PF) farmed in Asia. Microsatellite variation at five loci (*UNH216*, *UNH172*, *UNH123*, *UNH147*, *UNH222*) was more informative in characterizing stock differences than the mtDNA-RFLP markers that were based only on 14 restriction morphs. Contemporary microsatellite data showed that GIFT Nile tilapia had the highest mean expected heterozygosity (H_e=0.813), while GMT had the lowest (H_e=0.666). The unselected NIFI stock and SEAFDEC-selected were genetically similar, while GMT differed significantly from the other Nile tilapia stocks. Among the red tilapias, NIFIred had the highest H_e (0.715), while BFS had the lowest variability (H_e=0.567). The Taiwanese red tilapia HL and Thai NIFIred were genetically similar. Except for NIFI, most of the Nile and red tilapia stocks exhibited remarkably significant homozygote excess relative to Hardy–Weinberg Equilibrium (HWE), suggesting some degree of inbreeding. Asian Nile tilapias were more genetically diverse (pooled H_e=0.791; mtDNA nucleotide divergence value d_A=0.009) than the red tilapias (pooled H_e=0.697; mean d_A=0.004). This slight divergence between the Nile and red tilapias was also seen in the analysis of molecular variance (AMOVA; F_{CT}=0.0018) and in genetic distance and nucleotide divergence dendrograms. However, the AMOVA revealed that the greater percentage of variation (99.33%) in the total genetic diversity of the surveyed stocks is principally due to differences at the individual level and not between nor within groups. The significance of these results is that they reflect and lead to new inferences regarding the selective breeding and culture methods used in managing these farmed stocks.

Keywords: Mitochondrial DNA-RFLP; Microsatellite; Tilapia; *Oreochromis niloticus*; Genetically improved stocks

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Effects of bamboo substrate and supplemental feeding on growth and production of hybrid red tilapia fingerlings (*Oreochromis mossambicus* × *Oreochromis niloticus*)

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Abstract

Periphyton growing on artificial substrates can increase the production of herbivorous fish in aquaculture ponds. Periphyton may be an alternative or a complement for supplemental feed in fingerling production. Growth and production of hybrid red tilapia (*Oreochromis mossambicus* × *Oreochromis niloticus*) were evaluated in twelve 5 × 5 × 1-m^3 concrete mud-bottomed tanks with bamboo poles for periphyton production. Submerged tank wall surface was 16 m^2. There were three densities of 1.5-m bamboo poles: 0, 98 and 196 poles/25 m^2, resulting in 0, 18.5 and 37 m^2 of additional pole surface per tank. Tanks were stocked with red tilapia fry (average weight 1.2 g) at 25 fish $tank^{-1}$. At each substrate density, half of the tanks were fed with a fishmeal-based 35% protein diet at 5% body weight day^{-1}. Fish were harvested after 75 days. During the experiment, periphyton density on the substrates (ash-free dry matter [AFDM], ash and chlorophyll *a*) and water quality were monitored regularly. Water quality was favourable for fish growth and there were only minor differences between the treatments. Periphyton biomass density on the substrates initially increased and was subsequently reduced during the experiment due to fish grazing. Final mean (± S.E.) gross fish yields (g/25 m^2) without substrates were 850.3 g (± 73.7) without and 1225.7 (± 193.7) with feeding. With 98 poles $tank^{-1}$, gross yields increased to 1803.8 (± 79.1) without and 2141.8 (± 221.7) with feeding. With 196 poles $tank^{-1}$, yields were not or only marginally higher. Although more experiments are needed to optimize periphyton density in relation to fish size and stocking density, the results show that periphyton can replace or complement supplemental feeding in tilapia fingerling culture.

Keywords: Tilapia; Periphyton; Aquaculture; Tanks; Feeding

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Cloning, tissue distribution and hormonal regulation of stearoyl-CoA desaturase in tilapia, *Oreochromis mossambicus*☆

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Abstract

The stearoyl-CoA desaturase cDNA in tilapia (*Oreochromis mossambicus*) was cloned by RT-PCR and RACE, and it was compared with those in grass carp, common carp and milkfish. Nucleotide sequence analysis revealed that the full length of cDNA (1172 bp) clone encompasses 1008 bp open reading frame (ORF) encoding 336 amino acid residues. The deduced amino acid sequence shares 78–82% identity with the teleosts and 64–66% with mammals compared, and like these fish, the cloned tilapia stearoyl-CoA desaturase amino acid sequence conserves three histidine cluster motifs (one HXXXXH and two HXXHH), which functioned as non-heme iron binding sites, essential for stearoyl-CoA desaturase activity. RT-PCR and Northern blot analysis reveal that tilapia stearoyl-CoA desaturase is expressed only in liver, but the stearoyl-CoA desaturase expression in multiple tissues was observed in milkfish, grass carp and carp. Further, the hormonal regulation of stearoyl-CoA desaturase gene expression was investigated by a single injection of 17β-estradiol and testosterone. The results showed that the administration of 17β-estradiol to tilapia led to a greater increase in desaturase activity than testosterone, and higher doses of steroids produced greater increases in enzyme activity. The comparative RT-PCR analysis showed that the stearoyl-CoA desaturase mRNA level increased significantly in 17β-estradiol treated animals, especially in the groups receiving a single injection of 50 mg 17β-estradiol. This was reflected in the decrease in the saturated fatty acids and the increase in the monounsaturated fatty acids. The proportion of the polyunsaturated fatty acids was not affected.

Keywords: Stearoyl-CoA desaturase; RACE; PCR; Tilapia; Expression; Regulation

☆ The sequence reported in this paper has been deposited in the GenBank database (Accession No. AY150696).

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Detection of a chromosomal region with two quantitative trait loci, affecting cold tolerance and fish size, in an F_2 tilapia hybrid

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Abstract

We searched for genetic linkage between microsatellite DNA markers and quantitative trait loci (QTL) for cold tolerance and fish size (body weight and standard length) in two unrelated F_2 families of interspecific tilapia hybrids (*Oreochromis mossambicus*×*Oreochromis aureus*). The first experiment was based on a family of 60 fish scanned for 20 microsatellites. A second experiment was conducted with a family of 114 fish scanned for 6 microsatellites in one linkage group, in order to test for QTL found in the first experiment. This two-step experimental design was used in order to protect against "false positive" associations. In both families, significant associations were found for two loci within the same linkage group. The two QTL, near *UNH879* for cold tolerance, and near *UNH130* for body size, were estimated to be 22 cM distant from each other, with no interaction found between the two traits. One of these loci, *UNH879*, was also associated with sex determination. Distortion from the expected Mendelian genotypic ratio was observed for three markers: *UNH130*, *UNH180* and *UNH907*, suggesting linkage with a QTL affecting survival. These results identify a chromosomal region in the tilapia genome harboring several QTL affecting fitness traits.

Author Keywords: Tilapia; QTL; Cold tolerance; Body weight; Standard length; Microsatellites

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An investigation of sex determination in the Mozambique tilapia, *Oreochromis mossambicus*, using synaptonemal complex analysis, FISH, sex reversal and gynogenesis

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Abstract

The Mozambique tilapia, *Oreochromis mossambicus*, is known to have an XX female/XY male sex determination system. Analysis of the pachytene meiotic chromosomes in *O. mossambicus* and hybrids with *Oreochromis niloticus* demonstrated a region of diffuse lateral elements and differential staining in the long arm of bivalent 1 that was present only in heterogametic fish. Homology was also demonstrated between the chromosome pair 1 of *O. niloticus* (which has been previously demonstrated to be the sex chromosomes) and the same chromosome pair of *O. mossambicus* through fluorescent in situ hybridisation using probes prepared from the *O. niloticus* chromosome 1. This suggests that chromosomes in pair 1 are the sex chromosomes of the Mozambique tilapia. Meiotic gynogenetic progeny from *O. mossambicus* XY neofemales consisted of both YY and XY males but no females, in contrast to a previous study in which only YY male and XX female meiotic gynogenetics were produced in similar experiments. Autosomal genetic effects on sex determination were detected for the first time in this species.

Keywords: Mozambique tilapia; FISH; *Oreochromis mossambicus*; Sex chromosomes; Synaptonemal complex; Gynogenesis

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Recombinant bovine growth hormone treatment of tilapia: growth response, metabolic clearance, receptor binding and immunoglobulin production

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Abstract

Experiments were performed to examine the growth-promoting effects of recombinant bovine growth hormone (rbGH) in the euryhaline tilapia (*Oreochromis mossambicus*). A radioreceptor assay using a crude membrane preparation of tilapia liver revealed that rbGH was about 100-fold less potent than native tilapia GH (tGH) in displacing ^{125}I-labeled tGH. Bovine prolactin (bPRL) was equipotent to bovine GH indicating that the GH receptor of tilapia does not distinguish mammalian GH from mammalian PRL. When juvenile tilapia, weighing 1 g, were maintained at 28 °C and received intraperitoneal injection of rbGH at doses of 0.1, 1 or 10 μg/g weekly for 8 weeks, no significant effect on growth was observed. A second experiment examined weekly doses ranging from 1 to 50 μg/g for 16 weeks, using 1 g fish maintained at 23 °C. rbGH (50 μg/g) significantly increased growth after 14 and 16 weeks, although the growth rate was significantly less than those held at 28 °C. More pronounced growth-promoting effects were observed, however, when fish weighing 5 g and held at 29 °C were injected with rbGH at doses of 100 and 1000 μg/g once a week for 4 weeks. A single injection of a sustained-release formulation of rbGH (Posilac®, 100 and 1000 μg/g) also elicited growth-promoting effects in fish weighing 4 g and kept at 29 °C. Treatment with rbGH, Posilac® or bovine serum albumin (BSA) elicited significant increases in plasma levels of immunoglobulin (IgM) in a dose-dependent manner. By contrast, there was no change in plasma levels of lysozyme activity in rbGH- or Posilac®-injected fish compared with controls. An uptake and clearance study confirmed a slower decline in circulating levels of rbGH following Posilac® injection compared with rbGH in saline. There was no change in plasma concentration of tGH after rbGH treatment, indicating that GH secretion from the tilapia pituitary was unaffected by high plasma levels of rbGH. The relative refractoriness of juvenile tilapia to growth-promoting effects of rbGH compared with that of other species may be due to the specific nature of the tGH receptor in recognizing the homologous hormone.

Author Keywords: Tilapia; Plasma growth hormone; Plasma immunoglobulin; Receptor assay; Posilac; Plasma lysozyme

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An evaluation of co-extruded poultry silage and culled jewel sweet potatoes as a feed ingredient for hybrid Tilapia (*Oreochromis niloticus* × *O. mossambicus*)

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Abstract

Two experiments were conducted with hybrid tilapia to evaluate a meal made by extrusion co-processing culled sweet potatoes and poultry mortality silage (ESPFP). In both experiments, dried, cull sweet potatoes and fermented whole turkey carcasses (60:40 ratio, w/w wet basis) were co-extruded, dried, and hammer-milled to make the ESPFP test ingredient. The resulting ESPFP meal was included at 0%, 11%, 22%, and 33% by weight in isocaloric, isonitrogenous pelleted diets. In an 87-day growth trial, no significant differences were found in the growth parameters or carcass (market) yields among the treatment groups. Tank water quality parameters were also unaffected by inclusion of the experimental ingredient. A consumer panel found no significant differences in the sensory indices (aroma, flavor, and texture) of the fillets from fish fed with the graded levels of ESPFP in the diet versus those from fish fed the control diet. The digestibility of the diets containing the ESPFP meal was evaluated in a second trial. The apparent dry matter (DM), gross energy (GE), and crude protein (CP) digestibility coefficients were reduced linearly with increasing levels of the ESPFP meal in the diets ($P < 0.019$). However, the level of inclusion of the ESPFP meal had no effect on the apparent organic matter (OM) digestibility coefficient values among the diets. Acid detergent fiber (ADF) and acid detergent insoluble nitrogen (ADIN) increased linearly ($P < 0.001$) with increasing levels of ESPFP in the diets, indicating significant heat damage had occurred during manufacture of the test ingredient. The indigestible Maillard polymers formed during extrusion co-processing and drying of these two ingredients accounted for 93% of the reduction in protein digestibility in the diets and were a contributing factor to the reductions in DM and GE digestibility. Extrusion co-processing of culled sweet potatoes and poultry mortality silage produces an acceptable feed ingredient for hybrid tilapia that can be included at up to 33% of the diet without adversely affecting growth, market yield, sensory indices, or water quality as compared to a standard tilapia diet.

Keywords: Tilapia; Poultry carcasses; Sweet potatoes; Extrusion; Waste management

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Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects

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Abstract

The use of monosex fish is intrinsically desirable in a variety of fish species in a range of aquaculture production systems. The potential advantages sought from their use may include one or more of the following features: achievement of higher average growth rate, elimination of reproduction, reduction of sexual/territorial behaviour, reduction of variation in harvest size, and reduction of risk of environmental impact resulting from escapes of exotic species.

Fish as a group have systems of sex determination which are of considerable biological interest and significance for studies in evolutionary biology. However, they are very variable, relatively poorly understood and give rise to much variation in sex ratio between, and within, species. Enough is known, however, to enable us to say that these systems are often employed in ways which sharply distinguish the fishes from groups such as mammals, birds and reptiles. As a consequence, manipulations of sexual phenotype designed to produce monosex populations are not straightforward and the results are not necessarily predictable.

This paper reviews the techniques for production of monosex males, and considers in detail the case of the YY/GMT technology in the Nile tilapia, which is the only example of a genetic technology for the production of monosex males so far widely adopted by the aquaculture industry. The considerable benefits accruing from the use of GMT are described. An attempt at projecting future developments in this area of aquaculture is made.

Author Keywords: Tilapia; Monosex; GMT

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Compensatory growth in hybrid tilapia, *Oreochromis mossambicus* × *O. niloticus*, reared in seawater

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Abstract

Hybrid tilapia weighing 4.34 ± 0.03 g (mean ± SE) were reared in seawater at 23.8 to 27.0°C for 8 weeks. The control group was fed to satiation twice a day throughout the experiment. The other three groups were deprived of feed for 1, 2, and 4 weeks, respectively, and then fed to satiation during the refeeding period. At the end of the experiment, fish deprived for 1 week had similar body weights to the controls, whereas fish deprived for 2 and 4 weeks had significantly lower body weights than the controls. During the refeeding period, size-adjusted feed intakes and specific growth rates were significantly higher in deprived fish than in the controls, indicating some compensatory responses in these fish. Feed intake and growth rate upon refeeding were higher the longer the duration of deprivation. No significant differences were found in digestibility, feed efficiency or protein and energy retention efficiency between the deprived and control fish during refeeding, suggesting that hyperphagia was the mechanism responsible for increased growth rates during compensatory growth. During refeeding, relative gains in protein, lipid and ash, as proportions of total body weight gain, did not differ significantly among treatment groups.

Keywords: Compensatory growth; Feed deprivation; Food consumption; Feed utilisation; Hybrid tilapia

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Breeding new strains of tilapia: development of an artificial center of origin and linkage map based on AFLP and microsatellite loci

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Abstract

Based on ideas from plant breeding and the opportunities offered by molecular biology, a program was initiated in 1995 to derive genetically superior tilapia from a synthetic stock (artificial center of origin, ACO) produced by inter-crossing five groups of fish: *Oreochromis niloticus* [wild-type (*On*) and red (R*On*) strains], *O. aureus* (*Oa*), *O. mossambicus* (*Om*), and *Sarotherodon galilaeus* (*Sg*). Three-way cross families (3WC) and four-way cross families (4WC) have been produced, so that all four species are represented in the ACO. A genomic map has been created for each of the parents in an *Om* × (*Oa* × R*On*) family using microsatellite and AFLP (amplified fragment length polymorphism) DNA markers. The female (*Om*) parent had a total of 78 segregating markers (17 microsatellites, 61 AFLPs). Of these, 62 (13 microsatellites, 49 AFLPs) were linked in 14 linkage groups covering a total of 514 centimorgans (cM). The first generation (F_1) hybrid male parent had a total of 229 segregating markers (62 microsatellites, 167 AFLPs), of which 214 (60 microsatellites, 154 AFLPs) were linked in 24 linkage groups covering a total of 1632 cM. The construction of these maps is a key step in a molecular marker-assisted breeding program to detect quantitative trait loci (QTL) for cold and salinity tolerance and carcass quality in tilapia.

Keywords: Tilapia; *Oreochromis*; Genetic map; AFLP; Microsatellite; Cichlidae; Interspecific hybridization

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Expression of recombinant tilapia insulin-like growth factor-I and stimulation of juvenile tilapia growth by injection of recombinant IGFs polypeptides

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Accepted 24 June 1999

Abstract

Mature recombinant tilapia insulin-like growth factor-I (IGF-I) polypeptide was produced in *Escherichia coli* by cloning the IGF-I B to D domains with glutathione-*S*-transferase (GST, pGEX-2T vector). The recombinant IGF-I fusion protein, produced following induction of *E. coli* with IPTG induction and digestion with thrombin, appeared as a major protein band with a molecular mass of 7 kDa. Recombinant tilapia IGF-I ([GSPGIHM]-IGF-I) polypeptide bioactivity, as measured in a homologous [^{3}H]thymidine incorporation assay assessing concentrations ranging from 0 to 120 nM, was found to significantly stimulate cell uptake of [^{3}H]thymidine. The stimulatory effect of recombinant tilapia IGF-I polypeptide is suggested to be dose dependent. Recombinant tilapia IGF-I and IGF-II polypeptides at doses of 0.1, 0.5, 1 and 2 μg (g body weight per fish)$^{-1}$ were injected into juvenile tilapia once a week. At doses of 2 μg IGF-I (g body weight per fish)$^{-1}$ and doses of 2 μg IGF-II (g body weight per fish)$^{-1}$, there were significant increases (**$P < 0.01$) from week 5 onwards in both body weight (73% for IGF-I, 72% for IGF-II), weight gain (270% for IGF-I, 260% for IGF-II), and body length (33% for IGF-I, 34% for IGF-II) relative to a similarly treated GST protein control group and untreated group.

Keywords: Oreochromis mossambicus; Insulin-like growth factor; Protein expression; Growth promotion

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Ambient salinity modulates the response of the tilapia, *Oreochromis mossambicus* (Peters), to net confinement

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Abstract

The stress response of the euryhaline tilapia *Oreochromis mossambicus* adapted to either fresh water (FW) or salt water (Instant Ocean™, 950 mosm; (SW)) was investigated to establish the influences of ambient salinity in this species. The fish were considered to be adapted to the salinities as pre-confinement plasma cortisol and glucose levels were typical for unstressed fish. Two hour net confinement increased plasma cortisol and glucose to a similar extent in both FW and SW. Individual plasma sodium and chloride levels were unaffected by confinement, although plasma Na:Cl ratio increased in FW. Confinement increased intestinal Na^+/K^+-ATPase activity in FW, but not in SW. In contrast, kidney Na^+/K^+-ATPase activity increased in SW only. Branchial Na^+/K^+-ATPase activity decreased with confinement in SW, but not in FW. In SW, confinement reduced the numbers of opercular chloride cells. Increased aging of the branchial chloride cell (CC) population of SW-confined fish was indicated by large numbers of apoptotic CCs in the interlamellar areas. This effect on the CC population was absent in FW-confined fish. Overall, confinement in SW-adapted fish had a more profound impact than confinement in FW-adapted fish. This is likely to have associated energetic consequences in terms of branchial oxygen and ATP consumption. Therefore, results suggest the possibility of different effects of confinement on subsequent growth in FW and SW.

Author Keywords: Tilapia; Stress response; Confinement; Ionoregulation; Na/K-ATPase; Cortisol; Glucose; Salt water; Electron microscopy; Gill ultrastructure; Chloride cells

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Aquaculture

Growth of five Asian red tilapia strains in saline environments

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Abstract

Growth of five Asian red tilapia strains (BFS, NIFI, FAC, PF and HL) were evaluated in brackish and seawater. Eight-week-old juveniles from the five test strains were size-matched with similarly aged *Oreochromis mossambicus* which served as internal reference. Fish were stocked at a ratio of 15 test:15 reference in 100-l tanks supported by a recirculating system. Commercial feed was given twice daily at 10–20% of the fish biomass. Growth, measured from length and weight increment at 10 weeks, was recorded. Statistical analyses on mean specific growth rates showed significant differences among the strains reared in seawater. The Philippine strain PF grew best in seawater while the Thai strain NIFI performed well in brackishwater. In the Philippines, red tilapias are farmed in intensive freshwater culture systems by few aquaculturists. Results of this study indicate that some Asian strains can be developed for use in more sustainable brackish and seawater culture systems.

Keywords: Red tilapia; Strain comparison; Seawater culture

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Aquaculture

Experimental studies on polyculture in closed shrimp ponds
I. Intensive polyculture of Chinese shrimp (*Penaeus chinensis*) with tilapia hybrids

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Abstract

Stocking performance and production in polyculture of Chinese shrimp (*Penaeus chinensis*) with red Taiwanese tilapia hybrids (*Oreochromis mossambicus* × *O. niloticus*) were determined by using 26 enclosures, each 5.0 × 5.0 × 1.8 m placed in a closed 1.7-ha seawater pond. In two factorial design (3 × 4), shrimp juveniles (body length 2.85 ± 0.16 cm) and tilapia hybrids weighing from 79.0 g to 193.8 g reared in net cages were stocked into 24 enclosures at a rate of 4.5, 6.0 and 7.5 shrimp/m^2 and 0, 0.16, 0.24 and 0.32 fish/m^2, respectively and reared by feeding commercial feed and by administration of chicken manure and chemical fertiliser. To evaluate cultural pattern on tilapia, the shrimp juveniles and the tilapia juveniles were stocked into two enclosures at a rate of 6.0 shrimp/m^2 and 0.24 fish/m^2 (outside the cages), respectively. Overall survival rate of shrimp was 78.6% and did not differ among treatments. Mean final sizes of shrimp decreased with increase in its stocking density. As stocking density of the shrimp increased from 4.5 shrimp/m^2 to 6.0 shrimp/m^2, mean shrimp yield increased from 325.4 ± 15.3 kg/ha to 522.2 ± 54.9 kg/ha. There was a pronounced influence of tilapia density on growth, survival and yields of shrimp at 6.0 shrimp/m^2. At 0.32 tilapia/m^2, survival rate (96.67%), final body length (10.40 cm) and yield (585.5 kg/ha) of shrimp were high. The optimum stocking density of shrimp and tilapia was 60,000 shrimp/ha and some 400 kg tilapia/ha, respectively. Ecological role and cultural pattern (in or outside a net cage) of tilapia in shrimp polyculture was discussed.

Keywords: Polyculture; Shrimp culture; Pond; Tilapia; Enclosure; Chinese shrimp (*Penaeus chinensis*)

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Changes in the fatty acid profiles of hybrid red tilapia, *Oreochromis mossambicus* × *O. niloticus*, subjected to short-term starvation, and a comparison with changes in seawater raised fish

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Abstract

Juvenile hybrid red tilapia of mean weight 52.9 ± 2.80 g were starved for 45 days, and the liver and muscle fatty acid profiles of fed and starved fish determined on Days 0, 24 and 45. A corresponding group of fish were seawater adapted and were sampled on Day 45.

In fed fish the total fatty acids in the livers (expressed in $\mu g\ mg^{-1}$ lipid) decreased with growth (45 days), from 816 ± 16 to 600 ± 7 and 821 ± 25 to 589 ± 23 in females and males, respectively. This decrease was significant by the 24th day. In muscle, however, the amount of fatty acids in total lipid increased with growth, in females from 365 ± 21 to 489 ± 6 and in males from 387 ± 17 to 480 ± 17 $\mu g\ mg^{-1}$ lipid. Compared with fed fish, during starvation the proportion of fatty acids in total lipid increased in both types of tissues but was still lower than at the initial level, significantly so in the liver.

Twenty individual fatty acids were quantified as percent of total fatty acids in liver and muscle tissues of fish from different treatments during this study. In starved fish, liver monoenes decreased significantly ($P < 0.05$), from 33.0 to 16.3% and 35.6 to 9.5%, and the percentage of polyunsaturated fatty acids (PUFA) increased significantly from 18.3 to 39.9% and 16.9 to 46.2% in females and males, respectively. Comparable trends were also observed in muscle, but in muscle the percentage of PUFA tended to be higher than in the liver.

The fatty acids that occurred in the highest proportion were oleic acid (18:1$n-9$), followed by palmitic acid (16:0) and docosahexaenoic acid (DHA; 22:6$n-3$), collectively accounting for

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Aquaculture

Genotype and environment: A comparative evaluation of four tilapia stocks in Fiji

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Abstract

The reproductive, survival and growth performance of four tilapia strains in Fiji, namely *Oreochromis mossambicus* (M), 'Israel' *Oreochromis niloticus* (NI), 'Chitralada' *O. niloticus* (NC) and Red tilapia hybrid (R) were evaluated in two culture environments currently used in Fiji (integrated and non-integrated farming) for three generations. Results showed significant differences among strains in all traits. Overall, the M strain had the highest breeding efficiency and average fecundity but the poorest growth rate. The NI strain showed the highest survival and a good growth rate but low breeding efficiency and fecundity. Although the R strain showed a good growth rate in favorable environments, it was prone to stress under less optimal conditions and had a relatively low survival rate and only average fecundity. The NC strain showed the best growth rate and feed conversion efficiency, relatively good breeding efficiency but average fecundity and survival. Based on a weighted performance across all traits, the NC strain was identified as the best performing strain in Fijian conditions.

Significant genotype–environment interactions estimated during harvest were due to a strong rank interaction in the R strain and also magnitude interactions in the NC and NI strains. Growth performance of the M strain showed the lowest response to quality of culture environment.

Future approaches to improving tilapia production in Fiji are discussed.

Keywords: Tilapia; Genotype and environment; Strain evaluation; Culture traits

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Aquaculture

Acute and chronic toxicity of tannic acid and spent bark of cinchona to tilapia *Oreochromis mossambicus*

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Abstract

Spent barks of cinchona, left after extraction of quinine and quinidine released tannic acid and colour in aqueous solution. The maximum amount of tannic acid and colour was recorded in 72–120 h. After 144 h tannic acid concentration of water ranged 0.01–0.015% of the dry spent bark. Static bioassay with analytical grade (AG) tannic acid and spent bark of cinchona showed that 96 h LC50 of tannic acid to tilapia (*Oreochromis mossambicus*) was 107.2 mg l^{-1} as AG tannic acid and 55 mg l^{-1} as spent bark (SB) tannic acid. The concentration of tannic acid having a significant effect on the opercular movements of tilapia were 85 mg l^{-1} as AG tannic acid and 30 mg l^{-1} as SB tannic acid. A concentration of 0.3 mg l^{-1} of SB tannic acid reduced the feeding rate of fish. Chronic toxicity testing showed that this dose also reduced the growth and reproduction of tilapia. Similar ill effects were produced by AG tannic acid only at a concentration of 10 mg l^{-1}.

Keywords: Toxicity; Tannic acid; *Oreochromis mossambicus*

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Evaluation of three species of tilapia, red tilapia and a hybrid tilapia as culture species in Saudi Arabia

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Abstract

The culture potential of three pure tilapia species, *Oreochromis niloticus*, *O. aureus*, *O. mossambicus*, hybrid tilapia (*O. niloticus* × *O. aureus*) progeny and Taiwanese red tilapia (*O. mossambicus* × *O. niloticus*) was evaluated in 10 m^2 concrete tanks receiving freshwater. Tilapia were compared for growth, survival, yield, and feed conversion ratio. The different lines investigated showed different responses during different growing phases (fry, fingerling, sub-adult and adult). Final mean weights after 392 days rearing were higher for hybrid tilapia (327 g) than those of *O. niloticus* (293 g), red tilapia (264 g), *O. aureus* (234 g) and *O. mossambicus* (168 g). Yield ranged from 6.5 kg m^{-3} (*O. mossambicus*) to 13.0 kg m^{-3} (hybrid tilapia) and 2.2 to 4.4 kg l^{-1} of water used, respectively. The feeding of tilapia up to satiation within 30 min twice daily gave very good feed conversion ratios; the overall average ranged from 1.24 (*O. niloticus*) to 1.63 (red tilapia). Survival after four growing phases was 80% (hybrid tilapia), 74% (*O. niloticus*), 72% (*O. aureus*), 61% (*O. mossambicus*) and 7% (red tilapia).

Overall performance, based on fry, fingerling, sub-adult and adult rearing and the ranking based on final mean weight, specific growth rate, survival, and yield proved hybrid tilapia to be the best candidate for intensive tank culture, closely followed by *O. niloticus* and *O. aureus*. *O. mossambicus* showed poor performance and red tilapia gave very low survival during the fry and larval rearing phases.

Keywords: Tilapias; Tank culture; Growth; Yield

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Aquaculture

Relationships among ration, salinity, 17α-methyltestosterone and growth in the euryhaline tilapia, *Oreochromis mossambicus*

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Abstract

The effects of long-term 17α-methyltestosterone (MT) treatment (10 mg MT kg^{-1} feed) and ration size on the growth of the euryhaline tilapia, *Oreochromis mossambicus*, in fresh water (FW) and seawater (SW) were examined. Tilapia were fed a limited daily ration, starting initially at 18% of body weight for yolk-sac fry and decreasing gradually to 4% at 126 days. Eight treatments were employed. Control and MT treatment groups were replicated in FW and SW using either fish fed the limited daily ration described above or fish fed twice that ration. On limited ration, control fish in SW grew to twice the size of their FW counterparts. Treatment with MT increased growth in both FW and in SW tilapia. Doubling the feeding ration produced a significant increase in growth in SW, but not in FW fish. The greatest growth was observed in SW, MT-treated fish on double ration which grew to $> 4.2\times$ the size of FW control fish on a limited ration.

Routine metabolic rate was measured in tilapia reared from the yolk-sac fry stage in FW or SW. The rate of oxygen consumption in the SW tilapia was 72.4 ± 11.3 mg kg^{-1} h^{-1} (mean ± SE, $n = 6$) and 148.2 ± 9.2 mg kg^{-1} h^{-1} in FW fish ($n = 6$). These data suggest that the reduction in routine metabolism in *O. mossambicus* in SW may account for the increase in growth of the SW animals over their FW counterparts.

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Effects of dorsal aorta cannulation on cortisol and other stress parameters in the euryhaline tilapia, *Oreochromis mossambicus*

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Abstract

In tilapia that are reared from yolk-sac fry in fresh water (FW), the mean level of plasma cortisol was 22.9 ± 3.4 ng per ml. For seawater-reared fish (SW), cortisol was 55.8 ± 5.5 ng per ml. For these measurements, blood was collected by vascular puncture in the hemal arch within 1-4 min after netting and anesthesia. It is likely that the difference in cortisol levels observed in FW- and SW-reared tilapia under these conditions reflects the established osmoregulatory function of this hormone in seawater in this species. Nevertheless, after 4 min we found that plasma cortisol rises two-fold in both FW and SW tilapia, most likely as a result of stress induced by the disturbance of netting and handling. Similar responses have been reported in a variety of teleosts subsequent to netting, handling, and the administration of anesthesia, in spite of the fact that these procedures may be undertaken quickly and efficiently. The elevation of cortisol, as well as other associated changes, may limit the utility of protocols that involve repetitive blood sampling either from one individual or from several individuals sharing the same tank.

For these reasons, we have developed a procedure using a vascular cannula to study various endocrine phenomena including time-course relations, circadian rhythms and hormone clearance in the tilapia. In order to clarify the utility of this procedure for physiological studies, we undertook measurements of plasma cortisol, leucocrit, hematocrit and resumption of feeding in FW-reared tilapia that were cannulated through the dorsal aorta for up to 40 days. Fish were sampled serially as follows: 10 min prior to the operation, during the surgery, and postoperatively at 30 min, 1 h, 6 h, and daily up to 40 days after surgery. In most animals, cortisol levels returned to basal levels and feeding was restored within 2-3 days after cannulation. Nevertheless, a few individuals showed irregularly high cortisol levels, accompanied by a chronic loss of appetite. After cannulation, all fish showed a significantly depressed leucocrit until 24 h. Thereafter, the leucocrit recovered in all individuals. Surgery resulted in a decline in hematocrit. In most fish, hematocrit recovered within 2-3 days. In a few individuals, however, hematocrit declined continuously, suggesting inadequate erythrocyte replacement. The results of this study show that cannulated tilapia can be obtained which display characteristics, including plasma cortisol levels, which are similar to those observed in the stable unstressed animal.

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Changes in an immunoglobulin M (IgM)-like protein during larval stages in tilapia, *Oreochromis mossambicus*

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Abstract

Changes in an immunoglobulin (IgM)-like protein (MLP) were measured using an enzyme-linked immunosorbent assay (ELISA) in larval tilapia, *Oreochromis mossambicus*, obtained from a non-immunized mother. MLP levels during pre-larval stages decreased gradually, as yolk was absorbed. At 12 days after hatching, all yolk had been utilized, and the onset of feeding and free swimming was observed. About this time, MLP dropped to its lowest levels. The MLP levels during post-larval stages increased rapidly. These findings suggest that the MLP detected in the pre-larval stages is derived from maternal fish, and that its anti-pathogenic role, if any, lasts until the onset of feeding. Moreover, it is likely that the MLP detected during the post-larval stages was IgM produced by larvae themselves. The transition from maternally-derived substances to autogenous humoral defence molecules is discussed in respect of non-specific defence processes in the serum.

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Retardation of ovarian growth and depression of serum steroid levels in the tilapia, *Oreochromis mossambicus*, by cortisol implantation

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Abstract

Female *Oreochromis mossambicus* were implanted with cortisol suspended in cocoa-butter for the evaluation of the chronic effects of cortisol on reproduction. Implant doses of 1.5 and 3.0 mg/g body weight, mimicking the effects of long-term chronic stress, suppressed various reproductive parameters over the 18-day treatment period. Most fish treated with cortisol showed reductions in body weight. Oocyte size and gonadosomatic index of treated fish became significantly lower than the control after 9 and 12 days of treatment, respectively. The retardation of oocyte growth was accompanied by depression of serum testosterone and oestradiol-17β levels.

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Serum cortisol response to handling stress and the effect of cortisol implantation on testosterone level in the tilapia, *Oreochromis mossambicus*

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Abstract

A tropical fish species (*Oreochromis mossambicus*) was used to study cortisol response to handling stress. Unstressed fish were found to have very low (<10 ng/ml) serum cortisol levels. Stressed fish showed a rapid and significant rise in cortisol levels within 4 min. The peak level, reached within 30 min of stress, was dependent on the severity of the stressor, being lower (about 64 ng/ml) in fish disturbed by netting, and higher (about 119 ng/ml) in fish captured and confined. Removal of the stressor resulted in a rapid return of cortisol to a normal level. Cortisol cocoa-butter implants were successfully used to elevate and maintain cortisol at a level characteristic of a stressed fish for 19 days. Cortisol implants of 1.5 and 3.0 mg/g body weight were found to depress testosterone levels significantly over the study period.

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Effect of 17α-methyltestosterone on the growth of the euryhaline tilapia, *Oreochromis mossambicus*, in fresh water and in sea water

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Abstract

These studies were aimed at determining whether: (1) rearing salinity influenced the growth of the tilapia, *Oreochromis mossambicus*, and (2) long-term 17α-methyltestosterone (MT) treatment of tilapia enhanced growth beyond that produced by masculinization alone. These studies showed that tilapia raised in sea water (34–36 ppt) grew to twice the size attained by freshwater fish under the conditions of our experiment ($P<0.01$). To evaluate the optimal pattern of MT treatment, four treatments identified as control, continuous, early, and delayed were employed. Early and delayed MT-treated fish grew significantly faster than controls in both salinities ($P<0.001$). The growth of tilapia continuously treated with MT exceeded that of all other treatments in both fresh water and in sea water and was three times higher than that of the controls ($P<0.001$). Most importantly, the growth of continuously treated tilapia exceeded the growth of early treatment tilapia by 30–50% despite the fact that both treatments induced nearly complete sex reversal (~99%).

These findings suggest that continuous treatment with MT offers considerable advantage over sex reversal alone in the commercial culture of the tilapia. Overall, the greatest growth was observed in seawater-reared tilapia which were continuously treated with MT and, these fish were 5–7-fold larger than freshwater controls. The practical applicability of the findings from our tank investigations was evaluated in full-scale pond studies in which tilapia were cultivated in freshwater polyculture with common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngdon idellus*), mud carp (*Cirrhina molitorella*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*). The administration of 17α-methyltestosterone consistently and significantly augmented the growth of tilapia (22%) and the carp species as well.

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The effects of temperature and salinity on growth and feed utilization of juvenile, sex-reversed male Florida red tilapia cultured in a recirculating system

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Abstract

In two experiments, juvenile, sex-reversed male Florida red tilapia (avg. wt.=0.56–1.20 g) were stocked into forty-two 0.33-m^3 indoor tanks at a density of 74 fish m^{-3} and growth and feed utilization compared for 54–58 days at temperatures of 22, 27 and 32°C and at salinities of 0 and 18 ppt (experiment one) or at 18 and 36 ppt (experiment two) under a 12 L: 12 D photoperiod. Fish were fed twice daily to satiation a 32% protein diet. Each treatment consisted of seven replicate tanks supported by a recirculating water system. While growth rates generally increased with increasing temperature and were markedly lower at 22°C than at 27 and 32°C, salinity modified the effects of temperature on growth: at 0 ppt, feed consumption and growth reached a maximum at 27°C, while at 18 and 36 ppt, consumption and growth were highest at 32°C. Under all temperatures, feed consumption and growth were higher at 18 ppt than at 0 or 36 ppt. The results suggested that, in freshwater, heating water to temperatures above 27°C is not justifiable, while at 18 or 36 ppt, heating water to 32°C can maximize growth rates without lowering growth efficiency. An important advantage of brackishwater (18 ppt) rearing under conditions of suboptimum temperatures was further suggested.

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Brackishwater tolerance of some species and hybrids of *Oreochromis* for use in lagoon aquaculture (Ivory Coast)

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Accepted 20 June 1991. ; Available online 23 September 2003.

Abstract

For a decade, the Ivory Coast has undertaken the promotion of its large lagoons by developing aquaculture in general and the culture of tilapia in particular. Thus far, only the feasibility of *Oreochromis niloticus* culture in freshwater has been demonstrated. Since only a very small area of the lagoon network is freshwater, any significant increase in tilapia production depends on their culture in brackishwater under satisfactory technical and economic conditions. Neither *O. niloticus* nor the lagoon species, *Sarotherodon melanotheron* and *Tilapia guineensis*, are suitable for culture under these conditions. An experimental program was set up to select a tilapia with high survival rate and fast growth in brackishwater. This program involved the species *O. aureus, O. mossambicus, O. urolepis hornorum*, and the hybrids *O. niloticus* × *O. aureus*, *O. mossambicus* × *O. niloticus*, *O. niloticus* × *O.u. hornorum* and *O. mossambicus* × *O.u. hornorum*. The trials were held in lagoon water with a salinity of up to 15 ppt, the maximum value recorded for the zones suitable for aquaculture in the lagoon. These trials allowed the selection of one species, *O. aureus*, and two hybrids, *O. niloticus* × *O. aureus* and *O. mossambicus* × *O. niloticus* with survival rates significantly higher than those of the other groups tested.

Comparison of the performances and respective advantages of these three groups leads to the choice of *O. aureus* in preference to the hybrids for brackishwater culture. The results of the present study are discussed in relation to salinity tolerance and growth data found in the literature about the species and hybrids tested.

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Interactions of varying dietary protein and lipid levels in young red tilapia: Evidence of protein sparing

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Abstract

A 12-week feeding trial was carried out with young red tilapia, a hybrid of *Oreochromis mossambicus* and *O. niloticus*, with a mean weight of 1.185 g. Three series of isocaloric, experimental diets of 15%, 20% and 30% protein content (by dry weight) and for each series, four diets of 6%, 12%, 18% and 24% lipid content were tested. At all three protein levels the best growth was obtained with diets of 18% lipid. Daily consumption (in mg/g fish day^{-1}) was correlated negatively to the digestible energy content of the diets, and overall rate of growth positively to the mean daily protein consumption (per g fish per day). The food conversion ratio ranged from 1.10 ($P_{30}L_{24}$) to 2.32 ($P_{15}L_{12}$), the protein efficiency ratio from 2.18 ($P_{30}L_6$) to 3.56 ($P_{20}L_{18}$) and apparent net protein utilization from 19.9% ($P_{15}L_6$) to 42.95% ($P_{30}L_{18}$), where P and L refer to dietary protein and lipid, and the subscripts to the approximate percentage. The carcass lipid and protein reflected the dietary regimes.

The study indicates the protein-sparing capabilities of young red tilapia. The protein-sparing capability increased with increasing dietary lipid content up to 18% and decreased thereafter.

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Effects of dietary α-cellulose levels on the juvenile tilapia, *Oreochromis mossambicus* (Peters)

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Abstract

Five artificial diets with dietary α-cellulose levels of 0%, 2.5%, 5%, 7.5% and 10% were prepared and their effects on growth, survival, food conversion rate, protein efficiency ratio, body condition factor and hepatosomatic index were evaluated for juvenile (2.55 g) *O. mossambicus*. The best growth rate, survival, FCR and PER were obtained with 2.5–5% supplemental fibre. Tilapia fed with the 10% cellulose-supplemented diet demonstrated depressed growth just as did fish fed the cellulose-free diet.

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The influence of maternal age and delayed initial feeding on the survival and growth of previously unfed *O. niloticus* (L.) and *O. mossambicus* (Peters) fry

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Abstract

Naturally fertilized eggs from four 0+, 1+ and 2+ *O. niloticus* and *O. mossambicus* females were artificially incubated at 28°C. All growth and survival trials were conducted at 28°C and to 20 days post-hatch in a recirculatory system containing 48 2-l compartments. Five samples, each of twenty 5-day-old fry representing each female were transferred to separate containers and the age of initial feeding of fry in each compartment progressively delayed. Fry were fed to excess at either 6, 9, 12, 15 or 18 days post-hatching four times a day. In both species feeding at 6 days (10 days post-spawn) resulted in maximum sized 20-day-old fry. Within each species and age-class and further delay in feeding resulted in a significant ($P<0.05$) reduction in size. The vulnerability of fry growth to delayed initial feeding varied significantly ($P<0.05$) between the species. When feeding commenced at 12 days post-hatch, 20-day-old fry from 0+, 1+ and 2+ *O. niloticus* females only realized 15, 25 and 36% of their maximum growth potential when compared with 38, 67 and 86% in *O. mossambicus*. Similar trends were noted for their specific growth rates and body condition. The longest delay in initial feeding to obtain a 50% probability of survival of fry from 0+, 1+ and 2+ broodstock at 20 days was 11, 5, 15 and 17 days for *O. niloticus* and 10, 11 and 16 days for *O. mossambicus*, respectively. The implications of the above findings are discussed with respect to the natural and artificial rearing of mouth-brooding tilapias.

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The use of alfalfa leaf protein concentrates as a protein source in diets for tilapia (*Oreochromis mossambicus*)

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Abstract

Chloroplastic and cytoplasmic alfalfa (*Medicago sativa*) leaf protein concentrates were tested as dietary replacements for fish meal in practical diets for tilapia fingerlings. Each concentrate was used to replace 15, 25, 35, 45 and 55% of the fish meal protein in diets containing 40% protein. Diets containing cytoplasmic leaf protein gave the best results, with growth rates higher than those obtained with a fish meal-based diet when the plant protein replaced up to 35% of the fish meal protein in the diet; higher inclusion levels of plant protein depressed growth. No mortalities were recorded during the 9-week test period with any of the experimental diets. It was concluded that the alfalfa leaf protein could be included at levels of up to 35% of the dietary protein in feeds for tilapia.

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Growth, feed conversion and protein utilization of Florida red tilapia fed isocaloric diets with different protein levels in seawater pools

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Abstract

Twelve outdoor pools (10 m^3) receiving flow-through seawater (37 ppt) were stocked with sexreversed male Florida red tilapia fingerlings (10.6 g mean wt.) at a density of 25 fish/m^3. Three isocaloric diets containing 20%, 25% and 30% protein of equal quality were tested for effects on fish growth, feed and protein utilization, and carcass composition during growout through full marketable size. Growth rate was high for all diets, with mean weight ranging from 440 to 464 g after 120 days, and survival ranging from 97.0 to 97.5%. There were no significant differences among diets in survival, specific growth rate, daily weight gain, feed consumption and conversion, carcass composition, and fish condition. However, protein efficiency ratio was significantly higher for the 20% protein diet than for diets with higher protein levels. The results demonstrate that Florida red tilapia can be reared in seawater from fingerling through marketable sizes more economically on a 20% protein diet than on diets containing higher protein levels.

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Potential of rapeseed meal as an alternative protein source in complete diets for tilapia (*Oreochromis mossambicus* Peters)

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Abstract

A 56-day feed trial was conducted to investigate the potential of rapeseed meal in practical diets for juvenile tilapias. Six isonitrogenous (38% crude protein) and lipid and carbohydrate balanced diets were formulated. The control diet contained fish and soyabean meals as principal protein sources; these were progressively substituted with rapeseed meal.

Fifteen per cent rapeseed meal effectively replaced soyabean meal whilst higher inclusion levels led to progressively poorer feed performance. Levels of glucosinolate in the rapeseed meal were measured and effects on thyroid histology observed. The central colloid regions in thyroid follicles of fish receiving high rapeseed diets were found to be eroded or completely absent from the lumen.

This study indicated a practical inclusion limit of 15% rapeseed meal in tilapia feeds. Various approaches towards the possible improvement of the nutritional value of rapeseed meal products for use in fish diets are also discussed.

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Interaction between test and reference populations when tilapia strains are compared by the "internal control" technique

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Abstract

Several strains of *Oreochromis niloticus*, *O. mossambicus* and their hybrids occur in the Philippines, and others are likely to be introduced or developed locally in the near future. Our objective was to study biological interaction. The paper reports on an experimental design in which "reference" fish are included in each replicate to provide internal statistical control.

Growth of 10 full-sib families from each of two domestic strains was compared. A third strain of red tilapia was mass spawned to provide reference fish. Thirty equal-sized fry from each family were matched with 30 red tilapia fry and reared for 8 weeks in laboratory aquaria. The fish were deliberately crowded to provide a "worst-case scenario" for the application of the reference-strain technique. The objective was to see whether behavioural interaction causes statistical or genotype × environment interactions that create problems in the analysis.

The test strains interacted biologically with the reference strain in different ways: the growth (change in length) of strain 1 only was negatively correlated with reference growth. Statistical interaction did occur in this extreme situation. We speculate that the reference-fish technique will be more useful in experiments in ponds or cages, where variable environmental factors induce positive, rather than negative, correlations between reference and test strains.

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Cold tolerance in maternal mouthbrooding tilapias: Phenotypic variation among species and hybrids

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Abstract

Cold tolerance in the tropical-subtropical tilapias (genus *Oreochromis*) is a trait of economic importance in temperate climates where growing seasons are 6–8 months long and overwintering of stocks is a necessity. Standardized short- and long-term cold-tolerance tests have been evaluated for quantifying cold tolerance within and among populations. These tests will allow selection of superior individuals and/or families which can subsequently be evaluated for their breeding value.

The short-term test can be conducted in 8–12 h compared with conventional and ambient cooling methods which require several days to several weeks. Rank-order of phenotypic means among species was identical for short- and long-term cold-tolerance methods. Irrespective of testing method, *O. aureus* was most cold tolerant, followed by *O. niloticus* (Egypt strain), *O. mossambicus*, and *O. hornorum*. Cold-tolerance means for hybrid populations were intermediate to the respective parental means, indicating no significant heterosis.

Body weight (range=2–90 g), gender, or color phenotype within populations were not significant factors affecting cold tolerance. Genetic and environmental factors influencing the phenotypic expression of cold tolerance are discussed.

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Evaluation of the salinity tolerance of *Oreochromis mossambicus*, *O. niloticus* and their F_1 hybrids[*1]

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Abstract

The salinity tolerance of freshwater-spawned and reared *Oreochromis mossambicus*, *O. niloticus* and their F_1 hybrids of various ages was studied. Several tests were conducted using three indices as practical measures of salinity tolerance: (1) mean survival time (MST); (2) median survival time (ST_{50}); and (3) median lethal salinity-96 hours (MLS-96).

Interspecific and age-specific differences ($P<0.01$) in salinity tolerance were observed in these species and their F_1 hybrids on the basis of MST and ST_{50} indices, with salinity tolerance generally increasing with age of brood. No significant age-specific differences ($P > 0.05$) in salinity tolerance were observed in all four groups on the basis of MLS-96 index. At the same salinity *O. niloticus* fry at ages from 15 to 90 days post-hatch exhibited significantly lower ($P<0.05$) salinity tolerance than *O. mossambicus* and F_1 hybrids. Changes in salinity tolerance were determined to be more closely related to body size than age.

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Inheritance of red body coloration in Taiwanese tilapias and in *Oreochromis mossambicus*

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Abstract

The inheritance of red body coloration has been investigated in different tilapia species. This coloration has become fashionable in recent years due to the increased price of red tilapias. Different genetic mechanisms were discovered in different species and even among different genetic groups of the same species. In Taiwanese tilapias, apparently descended from hybrids between *Oreochromis mossambicus* and *O. niloticus*, red body coloration appears to result from heterozygosity between two partially dominant alleles at one locus. The non-wild-type homozygote "white" is subvital and difficult to distinguish from red individuals. Red × red spawns are not true breeding in this group of tilapias. All-red progenies have been produced by crossing wild-type colored to "white" individuals. Red body coloration in *O. mossambicus* was found to be a simple Mendelian recessive.

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Production of all-female sterile-triploid *Oreochromis mossambicus*

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Abstract

All-female triploids were produced by heat shocking 2.5-min-old eggs which had been fertilized with sperm from a masculinized female (XX-♂). Induction of triploidy was confirmed using the estimates of red blood cell (RBC) nuclear volume. Ovaries of the control diploids were packed with oocytes, while those of triploids contained only one or two poorly developed oocytes, thus indicating the sterility of female triploids. The major disadvantage of normal triploidization is the inadvertent introduction of a few diploids (♀ + ♂), which can undo all the labour involved in the triploidization; but all-female triploidization avoids the problems associated with normal triploidization. This technique may have considerable potential for tilapia aquaculture.

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The dietary protein requirements of young tilapia and an evaluation of the least cost dietary protein levels

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Abstract

In this study our goal was to establish the most economical dietary protein content for tilapia culture. To this end we assessed the relationship of growth, measured as percent average daily gain (% ADG), food conversion ratio (FCR) and protein efficiency ratio (PER) of young of four tilapiine species, *Oreochromis mossambicus*, *O. niloticus*, *O. aureus* and *Tilapia zillii*, for which experimental growth data were available, in relation to body weight and dietary protein content (% protein).

The relationship of % ADG to % protein in young tilapia weighing less than 1 g or 1–5 g was found to be a second order polynomial quadratic function whereas FCR and PER were linearly related to % protein. % ADG, FCR and PER were correlated better to body weight (curvilinearly) than % protein in both size groups, and multiple regressions were derived between the above parameters.

The most economical dietary protein content was evaluated from the polynomial quadratic function utilizing 95% confidence limits and also from the multiple regressions incorporating FCR and % ADG for a set of nearly isocaloric diets (gross energy) of different protein content ranging from 12% to 44%. Data derived from the foregoing approaches showed that young tilapia weighing between 1 and 5 g require 28% of the diet as protein. This dietary protein content, however, is considerably less than the protein level which supports maximum growth, namely 34%.

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Feminization of *Oreochromis mossambicus* by the administration of diethylstilbestrol

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Abstract

Gonadally undifferentiated *Oreochromis mossambicus* fry were given different doses of diethylstilbestrol (DES) orally for 11 or 15 days and reared for 70 days. All-female populations were produced at doses >100 μg DES/g diet in both treatments. Mortality increased at higher doses (>500 μg/g). The hormone treatment significantly (P>0.0005) improved the growth performance of the sex-reversed fish.

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Single gene inheritance of red body coloration in Taiwanese red tilapia*1

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Abstract

Randomly selected red tilapia (*Oreochromis mossambicus* × *O. niloticus*) broodfish were mated in aquaria and small concrete ponds at a ratio of one male to three females. Eggs were collected from individual females and artificially incubated. Body color was examined when the fry were 2 weeks old. A phenotypic ratio of three red to one black colored tilapia was obtained. Results of F2 progeny obtained from crosses of various body color combinations of the F1 progeny showed that red body coloration was inherited as a single gene with incomplete dominance. The study demonstrated that of the six possible matings, pink × pink, pink × red, pink × black, red × red, red × black, and black × black, the first three produce only pink or red tilapia. Thus, it is suggested that RR is the genotype for pink color, Rr for red color, and rr for black color.

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*1 Contribution No. 76 from Tungkang Marine Laboratory.

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A preliminary evaluation of an industrial single cell protein in practical diets for tilapia (*Oreochromis mossambicus* Peters)

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Abstract

A 56-day feeding trial was conducted with juvenile tilapia (*Oreochromis mossambicus*), to evaluate an industrial single cell protein (Eurolysine Fodder Protein, E.F.P.) as an alternative component to fishmeal in complete diets. A control diet without E.F.P. served as a reference from which inclusion levels of 5, 10, 15 and 20% E.F.P. were investigated by the replacement of fishmeal. All diets were formulated to be isonitrogenous and isocalorific in terms of crude protein and digestible energy. On the basis of these feeding trials, Eurolysine Fodder Protein was found to successfully replace up to 40% of the fishmeal in the practical diet. However, fish fed 15 and 20% E.F.P. displayed a significant reduction in growth rate. At these levels, poor food conversion ratio, reduced net protein utilization and feed intake were attributed to an amino acid imbalance, the absence of attractants or possible deleterious effects of high nucleic acid levels.

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The use of seed of the leguminous plant *Sesbania grandiflora* as a partial replacement for fish meal in diets for tilapia (*Oreochromis mossambicus*)

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Abstract

Two trials were conducted with fingerling tilapia to ascertain the nutritive value of *Sesbania grandiflora* seed meal as a dietary replacement for fish meal in a practical ration. For the first experiment, autoclaved sesbania seed was used in the diets to replace 10, 15, 25 and 35% of the fish meal protein. In the second experiment the seed was used to replace 25% of the dietary protein after four aqueous treatments, designed to remove compounds toxic to tilapia. The survival, growth, and feed utilization efficiency were adversely affected as the level of heat-treated seed meal was increased in the food. The aqueous treatments improved the quality of the seed as food, but not to a level of performance obtained with fish meal. Apparently the seed contains non-thermolabile toxins that produce high mortality and severely reduce fish growth and feed utilization.

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The use of jack bean (*Canavalia ensiformis* Leguminosae) meal as a partial substitute for fish meal in diets for tilapia (*Oreochromis mossambicus* Cichlidae)

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Abstract

The use of jack bean (*C. ensiformis*) meal in diets for *O. mossambicus* was tested in two experiments. The first was designed to determine the effects of protein from jack bean meal treated by autoclaving for 30 min at 125° C and 15 psi, as a partial substitute for protein from fish meal. The percentages of dietary protein from jack bean meal were 0 (diet 1), 10 (diet 2), 25 (diet 3), and 35 (diets 4 and 5). Diet 5 was also supplemented with the amino acids lysine, arginine and threonine. The results showed a direct relationship between fish mortality and the increment of jack bean meal. In the second experiment, three methods were tested to extract the non-thermolabile toxins from jack beans using 25% canavalia seed protein as a partial substitute of the total protein in diets for tilapia. The results showed no significant differences in growth (weight gain, final weight) and food conversion rate between fish ingesting the diets containing the treated jack bean and the control diet ($P < 0.01$). It is concluded that canavalia seed meal is potentially useful as a partial substitute for fish meal in tilapia diets. However, caution must be exercised when using this protein source because of the presence of residues of non-thermolabile toxins in the meal.

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Acclimation of commercially cultured *Oreochromis* species to sea water — an experimental study

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Abstract

An experimental study was conducted on the acclimation of fresh water *Oreochromis* species to sea water in order to evaluate the possible marine culture of the species in the subtropical Red Sea waters of Saudi Arabia. Although *O. aureus*, *O. mossambicus*, *O. spilurus*, *O. niloticus* and *O. aureus/O. niloticus* hybrids withstand direct transfer to 18‰ salinity, the species exhibit different mortality rates when transferred directly to higher salinities (>21.6‰). The salinity range of 23.4‰–30.6‰ is the critical tolerance level for all the fish. Pre-acclimation to salt water and gradual transfer to higher salinities produced better survival rates. The species *O. aureus*, *O. mossambicus* and *O. spilurus* required a shorter acclimation time (4 days) than *O. niloticus* and *O. aureus/O. niloticus* hybrids (8 days) for a transfer to full-strength sea water.

A biphasic osmolality response with a sharp increase in the plasma osmotic concentration (within 6–12 h) and a gradual return to equilibrium were recorded in the fish directly transferred to 21.6‰ salinity sea water.

The body water content of the hybrids *O. aureus/O. niloticus* dropped to 72.2% from about 78% within 12 h after the transfer to sea water. The dehydration coincides with the increase in the plasma osmotic concentration of the fish.

Among the species tested, *O. aureus*, *O. mossabicus* and *O. spilurus* prove to be the more suitable for marine culture upon gradual transfer.

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The effect of high salt diet on the direct transfer of *Oreochromis mossambicus*, *O. spilurus* and *O. aureus/O. niloticus* hybrids to sea water

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Abstract

The effect of feeding a high salt diet on the survival rates of some fresh water *Oreochromis* (formerly *Sarotherodon*) species in marine culture was experimentally investigated. High salt diet (10% NaCl) was fed to *O. mossambicus*, *O. spilurus* and *O. aureus/O. niloticus* hybrids for a period of 4 weeks and the survival rates were estimated after each week by directly transferring the species to various salinity levels. Feeding of dietary sodium chloride considerably enhanced the survival rates of *O. mossambicus* up to 84%, and the *O. aureus/O. niloticus* hybrids and *O. spilurus* up to 62% and 50%, respectively, in sea water. Best survival rates were recorded after 2 weeks of feeding the salt diet for *O. mossambicus* and *O. aureus/O. niloticus* hybrids, whereas in *O. spilurus* best survival was not achieved until 3 weeks. Contrary to the sudden increase in plasma osmotic concentration recorded in the fish transferred directly from fresh water to 60% sea water, high salt diet feeding prior to the transfer resulted in only a slight increase in the plasma osmotic concentration in sea water.

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Changes in steroid concentrations during sexual ontogenesis in tilapia

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Abstract

Testosterone, estradiol and 11-ketotestosterone were determined by radioimmunoassay in whole body extracts of tilapia at various stages of ontogenesis: before, during and after sexual differentiation. The study was conducted on *Tilapia nilotica* (= *Oreochromis niloticus*), *T. mossambica* (= *O. mossambicus*) and *T. hornorum* in a series of intraspecific and interspecific spawn combinations. The concentrations of testosterone and estradiol measured in homogenates prepared from groups of individuals just after fertilization were relatively high (c. 1 ng/individual) and declined to undetectable levels in 3–4-week-old fry. In older fry (4–6 weeks), the concentrations of both steroids started to increase; however, the testosterone increase was tenfold that of estradiol. In 6–8-week-old fry measured individually, the testosterone concentrations in intraspecific spawns showed a clear tendency toward two peaks of distribution. This bimodality in testosterone concentrations probably reflects the presence of males and females with different testosterone contents in the population. In interspecific crosses characterized by 100% male progeny, the distribution pattern of testosterone was unimodal, which would be expected in a monoxexual population. Estradiol and 11-ketotestosterone concentrations in the young differentiated fry at this age were low in all cases. It is suggested, therefore, that, of the steroids examined in tilapia at the age of 6–8 weeks, only testosterone reflects the processes of sex differentiation.

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The effect of dietary ascorbic acid supplementation on hatchability, survival rate and fry performance in *Oreochromis mossambicus* (Peters)

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Abstract

The role of dietary ascorbic acid in the reproduction of tilapias, *Oreochromis mossambicus* (Peters), was investigated in three experiments. The first showed that ascorbic acid supplementation of broodstock feed (125 mg ascorbic acid per 100 g dry diet) improved hatchability and fry condition. In the second experiment, fry produced from broodstock fed a diet without supplemental ascorbic acid and themselves fed the same diet performed poorly in respect of growth, food utilization and survival rate. A third experiment was conducted in which broodstock were fed the diet supplemented with ascorbic acid and their progeny were fed the unsupplemented diet. These fry showed improved performance, in terms of growth, food utilization and survival rate compared to fry from the second experiment. This suggests that ascorbic acid supplementation of broodstock diets results in some transfer of the vitamin via the eggs to newly hatched fry resulting in some amelioration of ascorbic acid deficiency during the early stages of life.

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Duration of feeding and indirect selection for growth of tilapia*1

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Abstract

Duration of spontaneous feeding was observed at three times each day in a laboratory population of nine juvenile tilapia (*Oreochromis mossambicus*). Growth of the fish was measured as change in length and weight, and also as uptake of ^{14}C-labelled glycine by isolated scales. Duration of the first morning feeding was highly correlated with all measures of growth and was independent of initial size. Later feedings were not correlated with growth. Selection on feeding duration could be used to select indirectly for growth rate; this might be a valuable procedure where individuals in the population are not exactly the same age (i.e., where size-at-age is an inaccurate measure of growth).

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Tetraploid induction in *Oreochromis* spp.

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Abstract

The use of tetrapoloid broodstock in tetraploid × diploid matings has been suggested as a method of circumventing de novo triploid induction. Eggs from female tetraploids may also correct inherent developmental imbalances created by inducing polyploidy in diploid derived eggs. Tetraploid induction, using a combination of pressure and cold treatments, was attempted on two species of tilapia, *O. niloticus* and *O. mossambicus*, and their hybrid. The three genotypes were used in a full-factorial mating design under different induction regimes. Results indicated that allotetraploids were markedly more viable than autotetraploids in early development, yet both tetraploid types were subvital when compared to their diploid counterparts.

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Chlorinated secondary domestic sewage effluent as a fertilizer for marine aquaculture

II. Protein-supplemented prawn culture

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Abstract

The possibility of culturing *Penaeus indicus* and *P. monodon* on *in situ* production supplemented by protein addition in chlorinated secondary sewage effluent fertilized seawater ponds was investigated. The protein supplement was produced on site in the form of tilapia (***Oreochromis mossambicus***) cultured in similar effluent-fertilized seawater ponds using a continuous stocking/multiple cropping system. The projected production of 10 t ha^{-1} a^{-1} tilapia has the potential to supplement the production of 1.05 t *Penaeus monodon* a^{-1} resulting in an overall yield of about 500 kg prawns ha^{-1} per growing season. A major drawback of the system is the accumulation of toxic sludge on the pond bottom which adversely affects prawn growth and survival. *P. monodon* is better able to utilize the *in situ* pond production, particularly *Enteromorpha* sp., than *P. indicus*.