Feed the Future Innovation Lab for Collaborative Research on Aquaculture and Fisheries (AquaFish Innovation Lab)

AquaFish Technical Sessions at
Aquaculture America 2014
Seattle, Washington, USA
11 February 2016

Proceedings

Assembled by Amanda Hyman
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AQUAFISH INNOVATION LAB

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The mission of the AquaFish Innovation Lab is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. Bringing together resources from Host Country institutions and US universities, the AquaFish Innovation Lab emphasizes sustainable solutions in aquaculture and fisheries for improving health, building wealth, conserving natural environments for future generations, and strengthening poorer countries' ability to self-govern.

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2014 AquaFish Technical Sessions
AA 2014 – Seattle, Washington, USA
11 February 2014

Session Organizer: Dr. Hillary Egna
Organizing Committee: Jenna Borberg and Stephanie Ichien

On 11 February 2014, AquaFish Innovation Lab held two special sessions at the World Aquaculture Society's Aquaculture America 2014 conference in Seattle, Washington, USA. Eight presentations were made in the morning session titled "Low Cost Feed and Input Solutions for Small-scale Aquaculture in Developing countries," and twelve presentations were given in the afternoon session titled "Low-cost Solutions for Sustainable Small-scale Aquaculture in Developing Countries." These sessions covered research on sustainable aquaculture for small-scale farmers, featuring numerous current and past AquaFish participants from around the globe. The morning and the afternoon sessions were a success with a captive audience that offered challenging questions and provided insightful feedback. These sessions at Aquaculture America were valuable for not only the AquaFish community, but also other aquaculture researchers worldwide who strive to find practices to decrease the cost of inputs while still producing valuable products.

2014 AQUAFISH TECHNICAL SESSIONS AGENDA
AA 2014 – Seattle, Washington, USA

11 February 2014

Tuesday, 11 February 2014

AquaFish Technical Session 1 (10:30-12:30)
Low-Cost Feed and Input Solutions for Sustainable Small-Scale Aquaculture in Developing Countries

Chair: Kevin Fitzsimmons, AquaFish Co-PI

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Madhav K. Shrestha*, Nelson Pokhrel, Narayan P. Pandit and James S. Diana

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Chair (absent): Dr. Hillary Egna
Co-Chairs: Jenna Borberg, AquaFish Assistant Director of Research
Stephanie Ichien, AquaFish Monitoring and Evaluation Manager

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AquaFish Technical Session 1: Low-Cost Feed and Input Solutions for Sustainable Small-Scale Aquaculture in Developing Countries

Effect of different fertilization and feeding systems on water quality and growth performance in Nile tilapia *Oreochromis niloticus*

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Feed is the major input that increases production cost in aquaculture. Production system that decreases feed cost and optimizes productivity has to be explored. An experiment was conducted in 12 earthen ponds of 150 m^2 size for 120 days at the Institute of Agriculture and Animal Science (IAAS), Nepal to assess the effect of fertilization and feeding combinations on growth, production in Nile tilapia (*Oreochromis niloticus*) and water quality in production system. The experiment was conducted in a completely randomized design (CRD) with 3 treatments and 4 replications. The treatments were: fertilization only (T_1); fertilization + half feeding (T_2); full feeding (T_3). All-male Nile tilapia fingerlings of about 6.0 g size were stocked in all ponds at the density of 1 fish/m^2. The $T_1$and T_2 ponds were fertilized weekly @ 4 kg N and 1 kg P/ha/day using di-ammonium phosphate (DAP) and urea, whereas no fertilizers were applied for T_3 ponds. The T_2 and T_3 ponds were fed twice a day between 9-10 am and 3-4 pm, with a commercial pellet feed (25.0% crude protein) at 1.5 and 3.0% of body weight per day, respectively. Feed rations were adjusted fortnightly based on sampling weights. At harvest, the mean weight, daily growth rate and survival of Nile tilapia were not significantly different among treatments ($p>0.05$). The gross fish yield and net fish yield were significantly higher in fertilization + half feeding system (T_2) than sole fertilization system (T_1) and sole feeding system (T_3) ($p<0.05$). The cost per kg fish production ranged from NRs 95.1-150.0, which was significantly lower in fertilization + half feeding system (T_2) than sole feeding system (T_3) ($p<0.05$). There were no significant differences in dissolved oxygen, transparency, total alkalinity, total phosphorous and total Kjeldahl nitrogen among treatments ($p>0.05$). However, the soluble reactive phosphorous and chlorophyll-a were significantly higher in fertilization + half feeding system (T_2) than in sole feeding system (T_3) ($p<0.05$). This study demonstrates that fertilization supplemented with half feeding is more productive and economic than sole fertilization or full feeding system in mono-sex Nile tilapia culture.

TABLE 1. Growth performance of Nile tilapia in different treatments during the experimental period of 120 days. Data based on 150 m^2 water area. Mean values with same superscript in the same row are not significantly different (P>0.05).

	Treatments		
Parameter	**T_1**	**T_2**	**T_3**
Total stock number	150	150	150
Average stock weight (g/fish)	6.2±0.1 [a]	6.3±0.0 [a]	6.1±0.1 [a]
Total harvest number	42.3±11.0 [a]	65.3±8.4 [a]	52.8±2.3 [a]
Average harvest weight (g/fish)	246.0±97.5 [a]	343.2±64.3 [a]	248.7±26.3 [a]
Daily growth rate (g/fish/day)	2.0±0.8 [a]	2.8±0.5 [a]	2.0±0.2 [a]
Gross fish yield (kg/crop)	8.4±0.9 [a]	21.4±1.9 [b]	13.0±1.0 [a]
Net fish yield (kg/crop)	7.7±0.9 [a]	20.7±1.8 [b]	12.4±1.0 [a]
Cost per kg fish production (NRs)	125.4±9.6 [ab]	95.1±5.2 [a]	150.0±13.2 [b]

Testing induction of periphyton growth as a low-cost possibility for sustainable small-scale tilapia culture in Yucatan, Mexico

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In Yucatan aquaculture is not a common practice. The rural population perceives fish culture as an activity compatible with their agriculture production ways, and as a potential food and income source. The high cost of commercial feeds is one of the main problems limiting fish culture development in the region. The installation of substrates in the water column to promote periphyton development on them as natural food for Nile tilapia *Oreochromis niloticus*, a priori looks like a low-cost technology possibility for small-scale tilapia culture appropriate for the rural population of Yucatan.

Since there is no previous experience in periphyton-based aquaculture under Yucatan conditions, we first tested periphyton growth on cheap locally abundant substrates: corn cane, corncob, corn leaf, bamboo cane, guano stick, plastic bottle. Guano stick showed the best periphyton growth and longer durability than the other organic substrates.

Experiments on tilapia growth were carried out in tanks filled with well water without aeration or water renewal. Treatments were 'with' and 'without' substrates, guano sticks and plastic bottles providing an underwater hard surface area equivalent to 80% of the tank surface. Under inorganic fertilization without fish feed inputs, in the tanks with guano sticks tilapia weight and biomass at harvest were significantly lower than in tanks without substrates. This seems to be due to some substance from the guano sticks that negatively affected the fish. When under the same conditions (inorganic fertilization without fish feed inputs) plastic bottles were used as substrate, tilapia performance was similar with and without substrates. This discards the use of guano sticks and would indicate that inducing periphyton growth even on appropriate substrates would not have an advantage for tilapia culture, which throws out our a priori assumptions.

However, in all the experiments performed tilapia performance was poor in all tanks, with and without substrates, with inorganic fertilization and with comercial feed. This led us to search for a more general phenomenon that might be affecting tilapia growth, like the high alkalinity of the well water characteristic of Yucatan. High alkalinity affects chemical reactions and biological processes, so that photosynthesis leads to very high pH in still water exposed to direct sunlight. Thus, our next step will be to search for a cheap way to reduce alkalinity (like liming is used to increase it, or renewing water periodically) and then test again induction of periphyton growth as a low-cost possibility for sustainable small-scale tilapia culture under Yucatan conditions.

Effect of different feeding regimes on growth and production performance of air-breathing stinging catfish, shing *Heteropneustes fossilis* and major carps in pond polyculture

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The stinging catfish or shing (*Heteropneuestes fossilis*) is a high value, micronutrient dense, air-breathing fish that has a strong capacity to tolerate poor oxygen environments. Because of this, the culture of shing has grown substantially over the past decade in Bangladesh. Feed constitutes almost 80% of the total variable costs of producing shing, so methods to reduce feed inputs can provide significant benefits, particularly if fish are polycultured with carps that rely primarily on natural pond productivity rather than direct consumption of formulated feeds for their growth. A study was carried out at the Fisheries Field Laboratory at Bangladesh Agricultural University to evaluate the effects of reduced feeding regimes on the growth and production of major Indian carps, rui (*Labeo rohita*) and catla (*Catla catla*) in pond polyculture with shing over a 120-day growout period. The experiment comprised three treatments in nine ponds (100 m^2 area, 1.5 m depth) each stocked with an equivalent number of carps (catla, 20 and rui, 80) and shing (500); with full feeding daily (T1), half feeding daily (T2), and full feeding on alternate days (T3). All ponds were fertilized weekly (N:P = 2.0:0.5). Commercial pelleted feed was applied according to current culture practices (20% down to 5% body weight of shing) either daily (T1) or on alternate days (T3) at full ration level or at half-rations daily (T2; 10% down to 2.5% bw of shing). Pond water temperature, TDS, conductivity, total alkalinity, pH, dissolved oxygen, ammonia-nitrogen, phosphate-phosphorus and chlorophyll-a did not differ among treatments ($p > 0.05$), while transparency was reduced in T1. No significant effect of treatment on survival rates was observed among the three species. Specific growth rates (SGR) of rui and catla did not vary significantly among treatments, but SGR was slightly reduced for shing in T3 relative to T1. No difference in shing SGR was observed between the T1 and T2 groups. The mean harvest weight of shing was similar in T1 (full feeding) and T2 (half feeding) groups, while both were higher than T_3(alternative day full feeding) fish. The apparent combined feed conversion ratio (FCR; feed applied to body weight gain) was lower in T2 and T3 relative to T1. The production of each (of three) species was higher in T1 than the T2 and T3 groups. The combined net production for the three species was 3,300 kg/ha for T1, 2,136 kg/ha for T2, and 2,440 kg/ha for T3. Despite the higher net production of fish in T1, the benefit-to-cost ratio (returns - investment) was better for T2 (3.34) and T3 (2.97) than for T1 (2.55). This is largely due to the lower costs of feed associated with 50% feed reduction strategies. Thus, despite lower production levels, daily feeding at half ration levels was the most cost effective strategy.

Alternate day feeding is more cost effective than daily feeding for culture of milkfish in brackishwater ponds and sea cages

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The herbivorous milkfish (*Chanos chanos*) grows in salinities ranging from fresh water to full-strength seawater. It is the largest finfish aquaculture industry in the Philippines with 350,000 MT produced annually. Much of the production is moving away from traditional brackish water pond systems to culture in sea cages, where fish are grown more intensively with substantively greater feed inputs to the environment. Feeds constitute 50-60% of total production costs for milkfish. This study evaluated the effects of alternate day feeding as a potential cost containment strategy for production of milkfish in both brackish water ponds and sea cages. Studies were undertaken at aquaculture facilities of the Southeast Asian Fisheries Development Center (SEAFDEC) in the Philippines. Milkfish fingerlings were stocked at 0.5 fish/m^2 in 700 m^2 brackish water ponds or in triplicate 5x5x3 m floating cages at 35 fish/m^3 for culture in coastal marine waters. Fish were fed either daily or on alternate days with SEAFDEC formulated feeds initially at 7.5% of body weight/day given over four feedings per day. The amount of feed was reduced as the fish gained weight. Fish were cultured for 12 weeks in brackish water ponds and 14-18 weeks in the sea cages. Survival rates of fish grown in brackish water ponds under alternate day feeding (93%) were similar to that of fish given a daily feeding regimen (84%). Average body weight (ABW) of fish on alternate day feeding was slightly less (275.79 ± 19.5 g) albeit insignificant from that of fish fed daily (324.31 ± 17.13 g). The harvested biomass was similar among treatment groups (daily feeding, 99 kg; alternate day feeding 94 kg). The apparent feed conversion ratio (FCR), however, was substantially lower in fish subjected to alternate day feeding (1.50) than that of fish fed daily (3.41). Results show a 56% savings in feed associated with raising milkfish on alternate day feeding with little impact on total yield.

For studies with sea cages, fish survival rates were similar between alternate day (89%) and daily (83%) feeding groups. The duration of culture for stocks fed on alternate days was longer and the ABW at harvest was smaller compared to stocks fed daily, indicating fish fed on alternate days grew at a lower rate. However, the total harvested biomass (615 ± 42.36 kg, alternate day; 629.67 ± 6.01, fed daily) and estimated value of the harvest was similar between the two groups. On the other hand, the amount of feed consumed and the corresponding cost of feeds were significantly lower in stocks fed on alternate days compared with stocks that were fed daily. The apparent FCR was lower in the alternate day (2.25 ± 0.15) relative to daily (3.2 ± 0.06) feeding groups. This resulted in savings in feed cost of 31.74% in the alternate-day fed group. Collectively, these results suggest that alternate day feeding provides a significant cost savings over the traditional management approach of feeding milkfish on a daily basis in both brackish water ponds and sea cages. Considering similar findings were observed with tilapia pond culture, the cost-containment approach of feeding on alternate days may prove generally useful for the culture of herbivorous fishes.

Effect of feeding level and frequency on performance of *Oreochromis niloticus* fed diets containing moringa leaf meal and sunflower seed cake

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A study was conducted for 90 days to assess the effect of feeding level and frequency on growth performance and feed utilization of *Oreochromis niloticus*. Three feeding levels i.e. 1, 2.5 and 5% of body weight, and two feeding frequencies (daily and skip a day) were tested. The experimental diet contained 28.41% crude protein mainly from *Moringa oleifera* leaf meal and sunflower seed meal. *O. niloticus* fingerlings with average weight of 9.3 ± 0.12 g were stocked at a density of 3 m^{-3} in 18 concrete tanks each with surface area of 7.06 m^2 and depth of 1 m. The experiment design was 3 × 2 factorial with the feeding levels and frequencies as factors randomly assigned to the tanks in triplicates. Weight and feed intake was recorded fortnightly for whole of experiment duration which was 90 days. Both feeding levels and frequencies had significant effect ($P<0.05$) on average daily gain (ADG), specific growth rate (SGR), daily feed intake (DFI), feed conversion ratio (FCR) and protein efficiency ratio (PER) as shown in Tables 1 & 2. There was a significant interaction between feeding level and frequency.

Findings from this study suggests that diets with moringa leaf meal and sunflower seed cake as major sources of protein should be fed to *O. niloticus* daily at 5% of body weight for better growth and feed utilization.

Table 1: Effects of feeding level on tilapia performance (Mean ± SE, n=3)

Variable	Feeding level		
	5%	2.5%	1%
ADG (g $fish^{-1}$ day^{-1})	0.27±0.04^a	0.16±0.01^b	0.10±0.02^b
SGR (% day^{-1})	1.35±0.11^a	0.96±0.05^b	0.69±0.08^c
DFI (g $fish^{-1}$ day^{-1})	0.72±0.13^a	0.30±0.04^b	0.12±0.02^c
FCR	2.61±0.20^a	1.96±0.28^b	1.08±0.07^c
PER	1.39±0.11^a	2.00±0.29^b	3.32±0.20^c

Table 2: Effect of feeding frequency on tilapia performance (Mean ± SE, n=3)

Variable	Feeding frequency	
	Daily	Skip
ADG (g $fish^{-1}$ day^{-1})	0.20±0.04^a	0.15±0.02^a
SGR (% day^{-1})	1.09±0.12^a	0.90±0.10^b
DFI (g $fish^{-1}$ day^{-1})	0.51±0.13^a	0.25±0.06^b
FCR	2.25±0.29^a	1.52±0.20^b
PER	1.85±0.29$_a$	2.62±0.31^b

^{a,b,c} Different superscripts in the same row indicate significant difference ($p<0.05$)

Mobilization and recovery of energy storage in Nile tilapia submitted to fasting and refeeding

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Physiological responses caused by starvation affect fish metabolism and essential metabolic processes are maintained at the expenses of endogenous energy reserves, resulting in changes and progressive depletion of body tissues. The aim of this study was to evaluate the carcass composition in Nile tilapia juveniles (chitralada Thai strain) during periods of fasting and refeeding.

Juveniles (body weight 26.37 ± 3.77g) were randomly stocked into 32 tanks in 150 liters with a continuously flowing water and constant aeration. Four treatments and three replicates were established: FC (control treatment fed daily), F1 (one week of fasting and ten weeks of refeeding), F2 (two weeks of fasting and ten weeks of refeeding), F3 (three weeks of fasting and ten weeks of refeeding). Fish were fed to apparent satiation with commercial diet (32% crude protein), three times a day (9, 14 and 17h). At the beginning of the experiment and during periods of fasting (1, 2 and 3 weeks) and after 10 weeks of refeeding, fish were anaesthetized with benzocaine (0.1 g/L), weighted and carcass samples (n=8 fish per treatment) were taken for analysis of lipid, crude protein, ash and moisture. The data were analysed by the software Statistical Analysis System (SAS 9.1). The means that showed significant differences between treatments were compared by Tukey test, at 5% of significance.

The results indicated that during periods of fasting in F1, F2 and F3, fish presented intense mobilization of body lipid. However, after 10 weeks of refeeding in F1, F2 and F3, the content of lipid in the body increased, and F3 was higher compared to FC. Percentages of moisture in carcass were higher during fasting in F1 and F3 than in FC treatment, but, after refeeding, only F3 changed in relation to FC control treatment. Ashes in F1, F2 and F3 treatments were higher than in FC, but after 10 weeks of refeeding no differences were found among the treatments. Crude protein did not differ among the treatments during the periods of fasting and after the refeeding. In conclusion, this study showed that lipid reserves in Nile tilapia juveniles are affected by food restriction, however, after refeeding fish recovers and the body composition equals to the control treatment (FC).

Table 1 – Effects of fasting and refeeding on carcass composition of Nile tilapia juvenile. Mean values (±dp) of body mass (g), lipid, crude protein, ash and moiture were determined in % total dry matter basis. FC (control treatment fed daily), F1 (one week of fasting and ten weeks of refeeding), F2 (two weeks of fasting and ten weeks of refeeding), F3 (three weeks of fasting and ten weeks of refeeding).

Weeks of Fasting/Refeeding	Treatments	Body mass (g)	Lipid (%)	Crude Protein (%)	Ash (%)	Moisture (%)
	FC	40.10 ± 1.05 a	5.25 ± 0.51 **a**	13.05 ± 0.46 **a**	3.87 ± 0.22 **b**	78.49 ± 0.64 **b**
1-WF	F1	30.00 ± 1.08 b	3.89 ± 0.82 **b**	13.05 ± 0.62 **a**	4.12 ± 0.27 **a**	80.06 ± 0.98 **a**
	FC	48.50 ± 0.84 a	6.00 ± 0.85 **a**	12.85 ± 0.75 **a**	3.49 ± 0.44 **b**	79.24 ± 2.02 **a**
2-WF	F2	29.40 ± 066 b	3.06 ± 0.47 **b**	12.50 ± 0.92 **a**	4.36 ± 0.23 **a**	79.68 ± 1.46 **a**
	FC	53.60 ± 2.71 a	6.25 ± 0.36 **a**	12.97 ± 0.65 **a**	3.63 ± 0.27 **b**	79.38 ± 1.19 **b**
3-WF	F3	28.70 ± 0.66 b	2.72 ± 0.58 **b**	12.71 ± 0.55 **a**	4.44 ± 0.25 **a**	82.28 ± 1.45 **a**
	FC	136.30 ± 9.12 a	6.80 ± 1.98 **a**	13.42 ± 0.63 **a**	3.64 ± 0.28 **a**	77.00 ± 1.60 **a**
	F1	119.00 ± 1.95 b	7.16 ± 1.48 **a**	13.72 ± 0.65 **a**	3.64 ± 0.34 **a**	77.04 ± 2.10 **a**
10-WR	FC	125.60 ± 10.46 a	7.21 ± 0.58 **a**	13.07 ± 0.75 **a**	3.41 ± 0.15 **a**	78.15 ± 1.14 **a**
	F2	100.40 ± 3.04 b	6.89 ± 0.47 **a**	13.40 ± 0.67 **a**	3.46 ± 0.45 **a**	77.83 ± 1.46 **a**
	FC	163.90 ± 33.62 a	6.35 ± 0.92 **b**	13.57 ± 0.84 **a**	3.55 ± 0.40 **a**	77.91 ± 1.89 **a**
	F3	119.20 ± 6.47 b	7.77 ± 0.89 **a**	13.83 ± 0.39 **a**	3.91 ± 0.18 **a**	76.05 ± 1.32 **b**

Means followed by the same letter did not differ by Tukey test (P>0.05).

Effects of fertilization and feeding level on the productivity of tilapia pond culture in Ghana

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Tilapia pond culture in Ghana is constrained by the high cost of formulated feeds. Fish farmers therefore rely on farm-made feeds that are unbalanced leading to low productivity. This study compared the performance of Nile tilapia cultured in fertilized ponds and fed half the recommended ration of a commercial tilapia feed to fish raised in unfertilized ponds with full ration over a 7-month period. The study was conducted at the research station of the Department of Fisheries and Watershed Management, KNUST, Kumasi, Ghana using 6 ponds of sizes 200 -300m^2. Ponds were dried, limed at a rate of 10kg $CaCO_3$/ 100m^2 and stocked at 2 fish m^{-2} with all-male tilapia fingerlings (20.0 ± 4.0g).Three ponds were fertilized with mono-ammonium phosphate (MAP) and urea at a weekly rate of 2gm^{-2} and 3gm^{-2}, respectively. Fertilization was strictly controlled by phytoplankton abundance through Secchi-disk readings (25 - 30cm). Fertilized ponds received half the ration (3 - 1.5 %) of body weight as feed twice daily whilst the other 3 unfertilized ponds had full ration (6- 3%). Fifty fish were sampled monthly to evaluate growth and adjust the feeding level. The results showed no significant differences in growth between fish fed half ration 202.9 ± 23.7g and full ration 204.6 ± 36.3g. Similarly, the total weight gained (kg), SGR (%/day), and FCR for the half and full ration ponds did not show any differences 101.7 ± 35.6; 101.9 ± 35.0, 2.41 ± 0.77; 2.41 ± 0.76 and 1.16 ± 0.28; 1.11 ± 0.17, respectively. The results of this study indicates that farmers could increase the productivity of their ponds, reduce production cost and increase profit through fertilization and feeding at half ration with formulated feed.

Enhancement of Pond Productivity by Organic Manure Fertilization and Supplementary Feeding in Kenya

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Nine experimental earthen ponds measuring 10x15m were fertilized using organic manure at 4 kg N and 1 kg P per hectare daily for one week before stocking with monosex tilapia at 3 fingerlings m^{-2}. Subsequent fertilization was repeated once a week while feeding was done *ad libitum* twice daily at midday and evening using locally prepared 30% crude protein. Selected water quality parameters were measures at hourly intervals from 08:00 to 16:00 daily with the aim of pond characterization during grow-out and to determine factor loadings for the physical, chemical and biological components of the pond units. The experiments are aimed at assessing the pond productivity under different management regimes and to facilitate designing of production systems and Best Management Practices (BMP). Water samples were collected from 5 cm below the water surface at 14:00 each day for nutrients analysis. Measurements of DO, temperature, conductivity, pH, hardness, TDS, Total phosphates, Total Nitrogen and ammonia were undertaken from February to July 2013 in the pond units under three fertilizer-feed regimes. Results from the study show that temperature increases during the day closely track the increase in the amount of dissolved oxygen in the ponds and that both fertilization and feeding enhance primary productivity. Close similarity (75%) was found between DO and Temperature characteristics of the pond but both compared at only 57% with pH. There was 98% similarity between conductivity and TDS in the three fertilizer-feed regimes. Total phosphorus and total nitrogen had 70.1% similarity in characterizing the treatments and compared favorably with Chlorophyll-a at 66% similarity. Temperature, pH and DO have a high factor loading on primary productivity, the nutrients phosphorus and nitrogen showed high factor loading on plankton biomass while TDS and Conductivity exhibited high factor loading on water quality and hence suitability for grow-out. Chlorophyll-a, pH, Conductivity, Total Dissolved Solids, Total Nitrogen, Total Phosphates, Dissolved Oxygen and Temperature could characterize up to 85% of the variation observed in the three fertilizer-feed regimes. The highest mean temperature of 24.97 was recorded at 14:00Hrs and this corresponded to the highest Dissolved Oxygen of 7.37 mg l-1. Significantly lower temperatures (22.3°C) were observed in fertilizer-feed treatment as compared to feed only treatment (22.8°C). Total phosphorus (0.995 mg l^{-1}) and total nitrogen (1.3735 mg l^{-}1) were significantly higher in fertilizer -feed regime ($F_{0.05,2,429}$=5.05; p=0.007 and $F_{0.05,2,594}$=26.14; p<0.0001 respectively). Total dissolved solids was significantly higher in the feed regime (258.76 NTU) as compared to fertilizer (243.51) or fertilizer-feed treatment (242.99) ($F_{0.05,2,594}$=4.70; p=0.009) while chlorophyll-a was 0.018, 0.029 and 0.032 mg l^{-1} in the respective treatments ($F_{0.05,2,429}$=85.06; p<0.0001). This study has shown that a combination of organic manure fertilization and ordinary/local feeds are suitable for sustaining suitable pond conditions for the growth of tilapia. Practices that promote effective seasoning and sustained nutrient levels such as fertilizer-feed are recommended for medium level management of tilapia grow-out in earthen ponds in Kenya.

AquaFish Technical Session 2: Low-Cost Solutions for Sustainable Small-Scale Aquaculture in Developing Countries

Production performance of dedhuwa *Esomus danricus* in monoculture and polyculture with carp in Chitwan, Nepal

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Small Indigenous Fish Species (SIS) are rich in micro and macro-nutrients. In spite of high nutrient value, their culture potential is often overlooked. Considering this fact, the present experiment was carried out to assess the production performance of Dedhuwa (*Esomus danricus*) in monoculture and polyculture with Carp at Phaphini, Chitwan District. The experiment was carried out in 9 farmers' ponds of 100 m^2 area for 270 days. The experiment included three treatments each with three replicates. Treatments included T_1 (Carp), T_2 (Dedhuwa) and T_3 (Carp+Dedhuwa). The ponds were treated with bleaching powder and lime prior to stocking. The stocking was done with 30 Silver carp (*Hypophthalmichthys molitrix*), 10 Bighead Carp (*Aristichthys nobilis*), 20 Common Carp (*Cyprinus carpio*), 15 Grass Carp (*Ctenopharyngodon idella*), 20 Rohu (*Labeo rohita*) and 5 Naini (*Cirrhinus mrigala*) for each 100 m^2in T_1 and T_3 while Dedhuwa was stocked at the rate of 300 per 100 m^2 in T_3 and 2,000 per 100 m^2 in T_2. Fish were fed with freshly made dough of rice bran and mustard oil cake (1:1) at the rate of 2% body weight once a day. Result showed that the growth and production of Carp except Bighead Carp was higher ($P<0.05$) in T_3 as compared to T_1 while that of Bighead Carp was higher ($P<0.05$) in T_1 than T_3. This showed that Dedhuwa had positive impact on the growth and production of Carp except Bighead Carp. Total net yield of Carp was higher ($P<0.05$) in T_3 than T_1. Net fish yield was lower ($P<0.05$) in T_2 than T_1 and T_3. Economic analysis showed that T_3 gave higher profit over T_1 whereas T_2 gave loss indicating that Dedhuwa monoculture is not economically viable. To sum up, Carp-Dedhuwa polyculture is suitable for small scale farmers because they can obtain better income and sufficient family nutrition by consumption of this nutrient rich fish.

Sustainable strategy for controlling fish desease conditions using banana *Musa sp.* Leaf extracts in Uganda

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Commercialization of aquaculture in Uganda is shifting management practices from subsistence to intensive levels. Small scale fish farmers, like hatchery producers, are adopting new technologies to enhance fish production. However, intensification of production systems is challenged with disease outbreaks that impact negatively on economic returns. Similarly, the common practice of using chicken manure by catfish hatchery farmers to produce zooplankton in nursery ponds is found to be a pathway for disease infections. Use of chemotherapeutants in the food fish industry is becoming less popular especially towards the less resourced farmers. Bio-control strategies are readily available and adaptable. Banana is a major food crop grown in Uganda with many communities deriving livelihoods from it.
Banana leaf extracts are used in a grow-out operation near Kampala city to control disease conditions. Initially, disease episodes caused mortalities ranging 14-100% in Tilapia fry (1-3g) and juveniles (20-50g). With repeated exposures to banana extract solution, the feed conversion ratio (FCR) improved from 3.2 to 0.75-0.87 as well as survival rates (about 85%). Bio-assays using several materials including salt, formalin and banana leaf extract to improve survival rates of catfish larvae were also evaluated. Addition of salt (1 mg/L) and banana leaf extract (3.2 ml/L) improved the survival of African catfish larvae cultured under aquaria conditions. Formalin (400µl/L) treatment had the lowest survival rates.
Results show how banana leaf extracts have a potential to be used in Uganda's aquaculture industry. This is a simple technology which small scale fish farmers can adopt and raw materials are locally available. Future research will focus on evaluating its chemical composition, effects on fish growth performance and its feasibility in aquaculture systems.

Role of collaborating programs in aquaculture development in Mali

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Mali is a country in West Africa with an area of 1,241,238 square kilometers. It has an important hydrographic network in the order of 4,500 km. The hydrography of Mali is essentially constituted by the basins of the rivers (Niger, Senegal and Volta). This hydrographic system maintains a set of natural and artificial lakes. The aquaculture potential is one of the most of West Africa. Before 2005 aquaculture production was estimated at 1300 tons of fish per year.

The constraints to the development of aquaculture were: the low level of training of producers, the low production capacity of fingerlings and the lack of infrastructure for production of the food fish.

From 2007 to 2010, the National Direction of Fisheries has received support from USAID which has enabled the implementation of AquaFish Collaborative Research Support Program (CRSP) through Oregon State University (OSU). The themes developed by the CRSP-Mali wore on: Pond Culture construction (Bamako), Rice Fish technology (Baguineda), and Fisheries Management (Selingue). The results achieved are: 385 persons trained, the mastery of rice/fish farming, the mastery of the artificial reproduction of wells catfish. CRSP-Mali has helped to strengthen the capacities of support services council of fisheries and of organized producers.

The development of the private production of fingerlings and feed for fish is one of the most important impacts. Mr. Seydou Toe is one of the greatest success stories. It is the first private producer of fingerlings private of Mali. In addition, it has contributed to the dissemination of techniques and technologies learned across the country. Finally he has developed kits of fry production of clarias by artificial reproduction in rural conditions. More than thirty copies of this kit are operating in the regions of Kayes, Koulikoro, Sikasso and Bamako.

Private investors have put in placed fish modern farms with a capacity production of fingerlings nearly 100 000 per year. The most important among them is the Diallo Farm. The unit of manufactures of food for fish has a capacity of 600 TM per year.

Kit for artificial reproduction of clarias of Seydou TOE

Profitability and adoption of two pond aquaculture best management practices in Ghana

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Despite the numerous benefits especially to developing countries from aquaculture, such as increased availability of low-cost, high-quality animal protein, poverty alleviation, increased employment, and foreign exchange earnings, most forms of aquaculture are perceived or known to have some adverse impacts on the environment. The fish farming industry in sub-Saharan Africa has been growing rapidly in recent years, facilitated by development partners. Along with growth and development there is the need to encourage the adoption of environmental best management practices (BMPs) to avoid new and costly environmental regulations, or in the absence of such regulations, degradation of the very environment that would sustain the industry. Considering the relatively dilute nature of effluents from fish ponds, the voluntary adoption of BMPs on these farms seems to be the most viable means of abating the negative impacts on effluent-receiving natural aquatic ecosystems. An important determinant of the voluntary adoption of any new technology by a farmer is his or her perceived relative profitability of the new technology, as compared to the existing technology or technologies been employed on that farm. Therefore, a study of the relative profitability of a new technology could serve as an indirect method of determining the adoption success of that technology in a particular region.

We applied two aquaculture environmental BMPs - pondwater reuse and the use of the relatively more expensive floating feed - to the culture of all-male *Oreochromic niloticus* in ponds on five demonstration fish farms in southwestern and central Ghana. Fish growth data was collected for over five months. We also collected adoption, production and marketing data in a survey we administered in person to 360 pond fish farmers in the study area over a three-year period. We applied the Linear Programming technique to determine the proportion of ponds on a typical farm that will be put under these two BMPs to maximize profits. Simulations were carried out with the General Algebraic Modelling System (GAMS) software.

Preliminary results indicate that under the existing production and marketing parameters, a reduction in the component of total production costs from the recommended feed type of between 10% and 23% will result in partial to full adoption of both BMPs. This reduction in feed costs may be achieved in three ways: reduction in total quantity of feed used while maintaining observed growth rates (increasing FCR), lowering the sale price of the recommended feed type (through subsidies or reduction in feed protein content), and the reduction of the total quantity of feed used in ponds that reuse water.

Further analysis will involve the application of the /Tradeoff analysis/Minimum-data technique to predict the adoption of these BMPs in the study area, based on relative profitability. We also will project actual BMP adoption rates from the three years of survey data, using the logistic adoption model. The results of these three exercises will then been combined to better understand the adoption patterns of the BMPs in the study area.

Using on-farm experiments to untangle the cuases of low productivity of tilapia *Oreochromis niloticus* grown in ponds in Ghana

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Pond-based aquaculture in sub-Saharan Africa has been plagued by low productivity. Many causes of this low productivity in tilapia ponds have been identified, but there is no consensus on the most important causes. To optimally allocate research, development, and extension resources to improve productivity, the multiple tangled causes should be better understood. Factors commonly cited for the problem include low-quality feed, lack of quality fingerlings, poor water quality management, inadequacy of control of reproduction in ponds, and poor stocking practices. Less frequently noted is improper pond construction and maintenance. Using data from on-farm experiments designed to promote wider adoption of selected better management practices (BMPs), the goal of the current study was to quantify the sources of variation in growth of tilapia in ponds, thereby identifying the factors with significant room for improvement.

The study was conducted in three pond aquaculture dominated regions of Ghana on eight farms over two six-month production cycles. Three of the farms participated in both cycles while the other five participated in one cycle. Each farm contributed four ponds for a total of 32 ponds and 44 experimental runs. The two BMPs studied were feed type and water source, combined in a 2 x 2 crossed factorial design. Fingerlings for the first production cycle were obtained from a local hatchery and stocked 3/m^2 at approximately 5g. For the second cycle fingerlings were obtained from a different hatchery, stocked 2/m^2 at approximately 20g, and catfish *Clarias gariepinus* fingerlings stocked at 20% of tilapia density after 10wks to control tilapia populations if sex reversal failed significantly. Feeding was varied from 5% to 2% body weight and fed twice daily and growth was monitored biweekly. Detailed pond morphology measurements were made at the end of the production cycle. We used partial regression analysis to decompose variation in growth among ponds, represented by the average size attained in 160 d.

The regression models accounted for 71.9% of variation (i.e., R^2) in growth. Feed type, source of fingerlings, source of water, control of reproduction, and stocking density accounted for 42.6%. Pond morphology uniquely accounted for only 2.6%, but combined with the other factors to account for a total of 18.3 percent of growth. Farms accounted for 11.0%. Commercial floating feed was the single most important factor accounting for observed growth, whereas the combined effect of fingerling source and control of reproduction followed closely. Many ponds were found to be extremely shallow, leading to true recalculated individual pond stocking densities of 3-17 fish/m^3. Thus, one important pathway by which pond depth mediated growth was through a strong observed negative relationship between stocking density and growth. Tilapia in some deep ponds with commercial floating feed and well controlled reproduction attained fast growth and an uncommon average of 361g in 160d of growout. Future extension needs to emphasize better pond construction, sourcing of good fingerlings, and economical uses of formulated feeds.

Estimating the actual and potential production capacity of aquaculture ponds in Ghana

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With a current population of over 25,000,000, and a growth rate of 2.3%, there is the need for Ghana to increase agricultural productivity to meet its food demands. Currently a net importer of fish and sea food products, Ghana is reported to have the potential to more than double its current agricultural production. Survey reports of aquaculture production from ponds in Ghana are similarly dismally low, averaging about 2500kg/ha. Sustainable intensification of aquaculture requires a clearer understanding of the gap between current and potential production and the causes of that gap. This study sought to develop a spatial database that includes the key infrastructure required for aquaculture in Ghana and to estimate the current production of Nile tilapia, *Oreochromis niloticus* from earthen ponds and potential production capacity if better management practices were adopted.

With the aid of GPS, the locations of approximately 170 farms in the Eastern, Western, Brong-Ahafo, Central and Ashanti regions, where pond aquaculture is concentrated in the country, were recorded and collated. Morphology was surveyed for a subsample of 160 ponds from these farms along with administering questionnaires to farmers about their management practices. These data were analyzed in conjunction with satellite imagery covering most of the country.
Information from field data, responses to questionnaires, and on-farm experiments provided robust estimates of current and potential total pond production capacity for tilapia in the country for aquaculture development planning. Preliminary results indicate that there may be significantly fewer viable pond-based fish farms in the country than the approximately 3,000 previously reported. However, experiments show that the production from these farms could easily increase fourfold with the adoption of better tilapia strains already available in the country and improvement in management practices.

An ecological approach towards optimizing pond-specific fertilization efficiencies for semi-intensive aquaculture

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The practical goal of pond fertilization is to stimulate the production of natural foods beneficial for culture organisms by systematically adding essential nutrients to the pond. Most frequently fertilizers are added to supply inorganic nitrogen (N), phosphorus (P), and sometimes carbon (C) to stimulate algal primary productivity, the foundation of the aquatic food web. However, every pond has individual characteristics (e.g., pond depth, source water, age, fertilization history, pond sediments) that can influence the fate of nutrient additions in each pond; this helps explain why what otherwise appears to be similar ponds can produce a wide spectrum of results, even when given identical fertilization treatments. Nevertheless, by incorporating ecological considerations in the fertilization strategy, the farmer can achieve the goal of maximizing production yields while minimizing economic costs on an individual pond basis.

This presentation describes how understanding pond ecological characteristics that influence algal productivity can provide time-specific and pond-specific fertilization requirements, as well as identify cost-effective fertilizer inputs. The centerpiece is the Algal Bioassay Fertilization Strategy (ABFS), a very simple visual algal response technology designed to identify both primary and secondary nutrients limiting algal growth in that pond water at that specific time. If a nutrient is primary limiting, the pond receives the full weekly rate; if the nutrient is secondarily limiting, the pond receives half the weekly rate; and if the nutrient is not limiting, then no additional fertilization is recommended for that time period. The ABFS was developed through PondDynamic/CRSP funding in the 1990s, and was presented at 3-day workshops throughout S.E. Asia in 2002. The ABFS does not require any water chemistry, or even literacy, for the pond's algal community to tell the farmer what they need (and do not need) to grow. Included among results from a 4-month grow-out trial in 400 m^2 earthen ponds comparing: 1) the ABFS, 2) a fixed-recipe approach (30 kg N ha^{-1} $week^{-1}$ and 15 kg P ha^{-1} $week^{-1}$), and 3) recommendations based on a computer model are relative Nile tilapia yields, nutrient uptake efficiencies, and fertilizer costs with each approach.

The presentation concludes with relevant pond-management guidelines (e.g., regarding pond depth and minimizing inorganic turbidity), and the ecologically based recommendations for optimizing pond-specific fertilization for semi-intensive aquaculture. These recommendations include using concentrated nutrient sources rather than manures, fertilizing N according to a fixed-recipe rate, and fertilizing with P and C according to weekly algal bioassay results. Higher, more consistent, and more cost-effective sustainable yields have great benefits for the rural farmer, as well as for research scientists wishing to minimize within-treatment variability when evaluating relative benefits of adding feeds to a fertilized pond system.

Stocking density analysis of two small indigenous species, punti *Puntius sophore* and dedhuwa *Esomus danricus* to improve sustainability of typical six-species large-carp culture systems in rural Nepal

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Small indigenous species (SIS) have been added to polyculture ponds in Nepal and been shown to increase the economic and nutritional sustainability for farmers. However, there has been little research on determining an optimal stocking density of these SIS, the resulting production of large carp, and the availability of SIS for household consumption.

Based on surveys conducted while on site, currently farmers do not intentionally stock SIS as they see no benefit to increasing densities above those that enter the system naturally. This research will provide evidence to help fisheries managers better understand SIS potential and advise on optimal pond stocking strategies. Also, SIS have been found in ponds that have been sealed off from outside water sources and not intentionally stocked. This finding highlights their prevalence in the area and the ease with which farmers could intentionally stock them.

Figure 1: SIS Stocking Strategy

The overall goal of this research is to identify an optimal stocking density of SIS within a typical carp polyculture system without significant negative impact on water quality or large carp growth. The project explores the feasibility of adding Punti (Puntius sophore) and Deduwa (Esomus danricus) at various densities to a typical 6-species large carp culture in Nepal (Bighead, Silver, Common, Mrigal, Rohu, and Grass carp). These additions will allow farmers to more efficiently use their pond space, and will increase the economic, nutritional, and environmental sustainability of carp culture. We anticipate that the addition of SIS to this culture system will increase yield by about 10% without reducing carp production or negatively impacting water quality.

Twelve 200m^2 ponds were stocked (August 2013) using 3 treatments and a control (Figure 1). Large carp densities (Figure 2), feed composition, and fertilizer were chosen based on the 'typical' and most common practices in the area under the advice of Dr. Madhav Shrestha, a professor of aquaculture and President of Nepal Fisheries Society (NEFIS). SIS stocking densities were chosen based on a literature review of recommended carp densities, and are widely varied in order to clearly show differential impact(s) and better identify an optimal stocking density.

Figure 2: Large Carp Stocking Strategy

Water quality measurements are being taken taken weekly, diurnal oxygen measurements are taken bi-monthly to estimate primary productivity, and partial harvests are taken monthly to assess carp growth and SIS numbers. During the final harvest (January 2014), ponds will be drained and all fish identified, counted, and measured. Periphyton growth will also be estimated using ceramic tiles.

	Punti (Puntius Sophore)	Deduwa (Esmosus Danricus)
Ponds 6,3,4 (Control)	0/ha , 0/pond	0/ha , 0/pond
Ponds 10,8,2 (Treatment 1)	25,000/ha ,250/pond	25,000/ha ,250/pond
Ponds 12,11,5 (Treatment 2)	50,000/ha ,500/pond	50,000/ha , 500/pond
Ponds 9,7,1 (treatment 3)	75,000/ha ,750/pond	75,000/ha 750/pond

Figure 1: SIS Stocking Strategy

Surface Feeders (50%)			Column Feeders (20%)			Bottom Feeders (30%)		
Species	*%*	#	*Species*	*%*	#	*Species*	*%*	#
Silver	30%	90	Rohu	10%	30	Common	15%	45
Bighead	20%	60	Grass	10%	30	Mrigal	15%	45

Figure 2: Large Carp Stocking Strategy

Environmentall friendly cage culture: A successful model of small-scale aquaculture for livelihood of fishing communities in Nepal

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This manuscript presents the current status and future scope of environment friendly small-scale cage fish culture in Nepal, which is practiced mainly with plankton feeder fish, such as bighead carp (*Aristichthys nobilis*) and silver carp (*Hypopthalmichthys molitrix*), in floating cages in natural lakes and reservoirs. The most important feature of this cage culture is absence of external feed to cultivate plankton feeder fish, with the fish subsisting on plankton available naturally in water column. It is popular among the traditional 300 families of fisher community, known as Jalari or Pode, living around lakes of Pokhara valley, and among the families displaced by the construction of hydropower dam in Kulekhani, Makwanpur. In these water bodies, there are over 2,400 cages of approximately 117,350 m^3 with estimated fish production of 250 mt/year. Such a cage fish culture has been in operation since three to four decades in Pokhara and two decades in Kulekhani. The productivity is varied from 1.6 to 4.3 kg/m^3 and contribution to national fish production is about 0.57%. However, its social impact is incomparable as the cage fish culture sustains family job and provides income to buy food and clothing, and to support the education of their children. The cage fish culture in natural lakes in Pokhara valley and Kulekhani reservoir has been appreciated as one of the successful farming model, contributing to mainstreaming the deprived and displaced fisher communities. Since then, the technique has been spread across the country with varying degree of adaptation to local conditions. Inclusion of grass carp (*Ctenopharyngodon idella*), which is famous for utilizing aquatic plants and is a fast grower as well as fetches relatively high market price, is more popular. Recent trend of its adoption suggests that cage culture with grass carp is becoming popular among farmers and possess further adoption potentialities. Small-scale cage fish farming has contributed remarkably to the improvement of living standards of the people, ensuring food security, creating additional jobs and augmenting incomes. This practice is recommended for expansion in other lakes and incoming reservoirs in the country, based on the inclusive doctrine of equal opportunity and sustainable development.

Evaluation of the functioning of farm dams in catchments in the Stellenbosch Area of South Africa

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The Western Cape Province in South Africa has a Mediterranean climate with warm, dry summers and wet, cold winters. Commercial farmers of agricultural crops such as grapes, citrus, olives and deciduous fruit are dependent on summer irrigation to maintain water supply for quality produce. However, excessive declines in water level of farm dams caused by withdrawal for irrigation could negatively impact aquaculture in multipurpose water impoundments. Furthermore, aquaculture activities in such impoundments might increase plankton production and the planktonic particles could clog irrigation systems. Changes in water quality caused by aquaculture might also negatively impact use of water for domestic purposes.

The study described events associated with integrated aqua-agriculture systems and explored how small impoundment (farm dams of 300 000 m^3 to 1 500 000 m^3 in volume) mitigate these effects increasing water supply in rural and peri-urban areas. Construction of small impoundments would convert land to aquatic habitat, but overall, the associated effort would probably increase local ecosystem complexity and be beneficial to expanding biodiversity.

The newly-established aquatic habitat gave rise to wetland and marshy areas and could improve and maintain ecological integrity of the lower reaches of the catchment. The study also placed aquaculture in perspective to wider nutrient loading on water resources via agriculture in pesticides and fertilizers.

Aquaculture product development and marketing innovations for Sustainable Small-Scale Aquaculture in Kenya

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Aquaculture production in Kenya stands at 48,770 MT, which is about 25% of the total fish production with aquaculture having experienced unprecedented growths of over 300% in the last three years.

AquaFish support in Kenya has big impact in the aquaculture growth in the country and the Kenya Government recognizes aquaculture as one of the key drivers of food security, employment creation and economic growth, and a major instrument for bringing gender parity in the economic sector. Despite the fast aquaculture global growth, aquaculture development in Kenya still faces a lot of challenges; these include weak aquaculture promotion programs and weak marketing systems.

A pilot project in three regions: Western, Rift Valley, and Central in Kenya was started in September 2011 through AquaFish CRSP to enhance profitability of small scale aquaculture operations in the rural areas through adoption of selected aquaculture best management practices (BMPs). The broad objectives of the project are: (1) scaling up innovations from previous ACRSP and AquaFish project successes and (2) accelerating BMP adoption rates in Kenya. The specific objectives of the project are to: (a) provide information on BMP adoption in Kenya, (b) quantify adoption of BMPs, (c) quantify production and financial efficiencies for BMPs adopters versus non-adopters and (d) assess economic benefits of adopting BMPs. Adoptions of the BMPs by some farmers have been very good and they have come up with marketing innovations for aquaculture products.

Farmers have formed groups/clusters and operate under one umbrella organ called the Aquacultural Association of Kenya (AAK). Several such groups of farmers are in operation and include Shama Fish Farmers Group in Central Kenya and Lurambi Farmers Cluster in Western Kenya.

Farmers who have adopted the BMPs formed production clusters that have developed synchronized production plans and established a strong marketing strategy. The innovation involves aquaculture product development, processing and value addition, market development and market outlets for final aquaculture products. The market outlets are strategically located and are operated by vendors who are directly linked to the farmers and to fish buyers and consumers. The farmers have seen their earnings from aquaculture increased by 150% and consumers of aquaculture products rise by 200%.

Low cost production systems for tropical gar *Atractosteus tropicus*

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The evaluation of growth performance of the tropical gar, *Atractosteus tropicus,* in different culture conditions has become a priority for new research in aquaculture in southeastern Mexico. During the last years there has been an increasing demand for native species culture in the regional market. A system that is becoming popular in rural areas consists of plastic or PVC circular tanks. To evaluate grow-out of gars, data were recorded from rural facilities located in the biosphere reserve "Pantanos de Centla" in Tabasco, Mexico. Facilities were based on a system including 9m-diameter PVC-lined circular ponds. Two thousand gar fry were stocked in each pond at the initial length of 11.06 cm and weight of 6.34 g. Commercial trout pellets were offered according to fry and juvenile size from 1.5 to 5.5 mm particles. In order to avoid cannibalistic behavior, fishes were classified by size at different times and water quality was maintained by pumping clean water from the river or water reservoirs. Fish weight and length were recorded monthly. Results indicate that tropical gars in this system grow faster than in traditional earthen-ponds and reach marketable size of 41.6 cm and 526.2 g in about 7 months of culture (fig. 1). Future experiments related with water quality and fish density will be necessary to determine profitable culture condition.

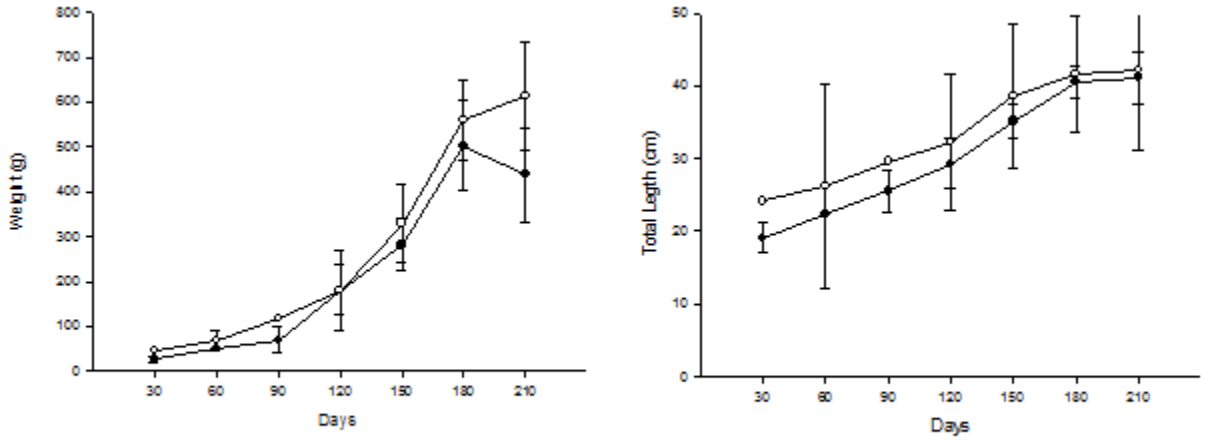

Figure 1. Average growth in weight (A) and Total Length (B) of tropical gar juveniles.