TOPIC AREA

Mitigating Negative Environmental Impacts

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ADVANCING SEMI-INTENSIVE POLYCULTURE OF INDIGENOUS AIR-BREATHING FISHES, KOI AND SHING, WITH MAJOR INDIAN CARPS FOR ENHANCING INCOMES AND DIETARY NUTRITION WHILE REDUCING ENVIRONMENTAL IMPACTS

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Mitigating Negative Environmental Impacts/Experiment/16MNE01NC

Collaborating Institutions and Lead Investigators

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Objectives

1. Compare combined polyculture of Koi with two major carps (Rohu and *Catla*) versus Koi monoculture under semi-intensive pond culture conditions.
2. Assess the effect of reduced feed ration in polyculture of carps and Koi. This experiment will identify a feed-reduction ration needed for equivalent or better production yields through increased nutrient utilization efficiency and impacts on the environmental water quality.
3. Assess economic and environmental benefits of combining Shing with Koi-carp pond polyculture.
4. Evaluate overall performance and economic returns of the improved management strategies and produce an extension factsheet outlining the benefits of the new technologies for transfer to farmers, extension agents, NGOs, and other stakeholders.

Significance

Air-breathing fishes provide a significant advantage for pond culture, as they tend to be resilient to harsh conditions, particularly during periods of low-oxygen, which can occur with high temperatures, drought, or poor water quality. Indigenous air-breathing fishes, such as Shing catfish (stinging catfish, *Heteropneustes fossilis*) and Koi (climbing perch, *Anabas testudineus*) are commonly found in open waters, paddy fields, and swamps of Bangladesh. Because of accessory respiratory organs they can even survive for a few hours out of the water. These fishes have been successfully cultivated in Bangladesh in recent years and command a high market value (DOF, 2012; Kohinoor et al., 2011), 3-7 times the value of other commonly cultured finfishes (striped catfish or *Pangasius* and tilapia). Both are currently in great demand by consumers for their taste and nutritional value (Hasan et al., 2007; Vadra, 2012; Vadra and Sultana, 2012). Shing catfish is particularly high in both iron (226 mg 100 g^{-1}) and calcium relative to other freshwater fishes and has been recommended in the diets of the sick and convalescent (Saha and Guha, 1939; Singh and Goswami, 1989). Culture of these indigenous species with high mineral content are important steps for increasing the yield and diversity of aquaculture products for consumption in Bangladesh and in reducing some types of dietary malnutrition, such as iron-deficient anemia (Dey et al., 2008; Micronutrient Initiative/UNICEF, 2004).

Production of Shing and Koi is currently limited to monoculture systems with high stocking densities and intensive use of commercial-grade feeds (30-35% crude protein). As feed can comprise a majority of total production costs (> 70%), there is limited participation by small homesteads utilizing the current practices for these fish and therefore creates a significant impediment to further expansion of this industry. Further, the use of high-levels of feed inputs has led to a persistent deterioration of pond water quality (eutrophication; cf. Chakraborty and Mirza, 2008; Chakraborty and Nur, 2012) and periodic mass mortalities and disease outbreaks. As most ponds are located near homesteads and villages, poor water quality and foul odors related to greater nutrient-loading impacts both local health and socio-economic tensions within the community (personal communication, Nural Amin, local farmer in Tarakanda, Mymensigh, July, 2012). Through field visits to Mymensingh, this research team observed firsthand that most air-breathing fish farms are often overfed, thus some of the problems associated with farming of air-breathing fishes can be alleviated through better management and implementation of semi-intensive culture practices. These problems may also be mitigated through polyculture, where excess nutrients and algae can be utilized by other species, for instance carps that feed primarily on plankton.

To this end, in Phase I of our project we evaluated whether carps could be incorporated into pond culture of Shing catfish. We found that addition of indigenous Indian carps (Rohu and *Catla*) enhances total fish yields and nutrient utilization of feed inputs over that seen with Shing monoculture alone. Shing growth was little impacted by culture with carps. Moreover, we found that reducing ration levels by as much as 50% from those currently used by the farming community (e.g., 20-5% body weight/day) provides additional return on investment of almost 100% in Shing-carp polyculture. We also demonstrated that Koi could be successfully cultured with either *Catla* alone or with *Catla* and Rohu under the reduced feeding ration established for Shing. However, our studies did not compare Koi-carp polyculture with Koi monoculture or whether the 50% reduction in feed inputs utilized produces similar growth and fish yields as could be seen with feeding at a higher rate. Therefore, the first experiment of the proposed research will assess whether mixed trophic polyculture of Koi and carps is a better technology than Koi monoculture and whether feed reductions can produce equivalent or better production yields and can improve nutrient utilization and water quality over current feeding practices.

Recent studies using high stocking densities (25-37 fish/m^2) and prohibitively high feed inputs (100% down to 5% body weight/day) suggest that both Shing and Koi can be cultured together (Chakraborty and Nur, 2012). We propose to extend the new semi-intensive Koi-carp technology developed here to evaluate whether Shing might provide additional increases in fish yields and returns on investment in Koi-carp polyculture. Indeed, farmers are now interested in understanding if culture of both air-breathing fishes with carps might provide economic advantages, particularly under reduced feed ration. Here we will assess the addition of Shing stocked at different densities in Koi-carp growout. To our knowledge, the incorporation of Shing, Koi, and carps in polyculture has yet to be evaluated and this could represent an additional technology for enhancing efficiency of food production in ponds, yield of nutritious fish, and farmer incomes.

Quantified Anticipated Benefits

1. Use of a mixed-trophic level polyculture production system will increase nutrient utilization efficiency and reduce negative environmental and social impacts (pond eutrophication) of producing Koi.
2. We anticipate improvements in environmental water quality for the culture of Koi with carp. Further improvements are likely to occur with reduced feeding, semi-intensive culture practices.
3. Successful implementation of feed-reduction strategies for Koi/carp polyculture will reduce feed costs by as much as 50%, thereby increasing production of high-value crops as farming of these fish will become more attractive to low-income homestead farmers.
4. We anticipate greater production yields (kg) of fish will benefit human nutrition, as it will enhance income and availability of fish for rural farming households. This is particularly true of air-breathing fishes, since Shing catfish are high in micronutrients commonly lacking in the diet of rural Bangladeshis.

5. Overall, we anticipate that semi-intensive culture of high-value Shing catfish with Koi-carp will improve earned incomes through greater yield of fishes and promote more sustainable production of fish with high nutritional value in Bangladesh and other regions of Asia.

Research Design and Activity Plan

Location

These studies will be performed onsite at the Fisheries Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. Water quality analysis will be performed at the Water Quality and Pond Dynamics Laboratory (BAU). Dr. Sadika Haque at the Dept. of Agricultural Economics (BAU) will conduct the economic analysis for this experiment.

Methods

*Experiment 1***.** Compare combined polyculture of Koi with two major carps (Rohu and *Catla*) versus Koi monoculture under semi-intensive pond culture conditions and assess the effect of reduced feed ration in polyculture of carps and Koi.

Null Hypothesis: No differences in growth efficiency, water quality, or economic returns are observed with koi farming with inclusion of carps under intensive culture practices (no pond fertilization) or semi-intensive culture with fertilization/reduced feeding strategies.

This experiment will evaluate 75% and 50% reduction in daily ration to identify the feeding rate yielding better economic returns for semi-intensive Koi-carp polyculture production. We will test the effects of full or reduced-feeding (2) on growth, production yield, and economic profitability (cost-benefit analysis) to minimize both costs and mortality due to poor water quality. As an additional benefit, this design will also test whether the current practice of Koi monoculture could be better managed (reductions in eutrophication) by the addition of carps. Two Indian carps, Rohu (*L. rohita*) and *Catla* (*C. catla*), will be raised with Koi (climbing perch, *A. testudineus*) in mixed-culture ponds. The feed reduction strategies will be implemented using the following experimental design:

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Rohu (*L. rohita*)	0	80 (0.8/m^2)	80 (0.8/m^2)	80 (0.8/m^2)
Catla (*C. catla*)	0	20 (0.2/m^2)	20 (0.2/m^2)	20 (0.2/m^2)
Koi (*A. testudineus*)	500 (5.0/m^2)	500 (5.0/m^2)	500 (5.0/m^2)	500 (5.0/m^2)
Fertilization	0	0	4:1 (N: P)	4:1 (N: P)
Feeding Protocol	Full Daily Ration	Full Daily Ration	75% Daily Ration	50% Daily Ration
Replicates (*n*)	4	4	4	4

This design contrasts the current monoculture intensive practice of Koi farming (T1), against treatments incorporating carps under intensive practices (T2), or culture with reductions in daily feeding (T3, T4). As carp farming requires significant primary production, levels that may not be achieved under restricted feeding, ponds will be fertilized weekly for these groups (T3, T4). As fertilizer is roughly 14% of feed costs, it is anticipated this design will prove more efficient and profitable than with full-feeding alone (T1, T2). The treatment groups will be randomly assigned to ponds (N =16, 100 m^2, 1.5 m depth). Prior to flooding and stocking, the ponds will be dried, re-excavated, and limed (25 g $CaCO_3/m^2$). They will be fertilized initially at 28 kg N and 5.6 kg P/ha prior to stocking. During the production period (120 days), T3 and T4 ponds will be fertilized at a rate of 28 kg N/ha/week and 5.6 kg P/ha/week. Full rations of feed (30% crude protein, commercial grade) will be administered by feeding to satiation, determined empirically every two weeks. Based on the current practice fish are fed 20%-5% bw/day with 5% declines at monthly intervals. The reduced-feeding groups will receive 75% and 50% less feed, based on values derived from T1 and T2. Feed amounts will be recorded for cost-benefit analysis performed at the end of

experiment. All ponds will be sub-sampled every 14 days to collected growth data (mean fish length and weight).

Water quality will be monitored daily (dO2, pH, turbidity/ secchi-disk depth), while additional parameters will be measured weekly or fortnightly by the Water Quality and Pond Dynamics Laboratory at BAU: ammonia, nitrates, total phosphate, alkalinity, chlorophyll-a.

Production yields (market weight, kg), estimated market returns, feed input costs (feed, fertilizers, labor, fingerlings), and labor costs will be gathered for all treatment groups at the end of experiment for marginal cost-benefit analysis by Dr. Sadika Haque (BAU).

All treatments will be tested for significant differences in growth (mean length, weight X time), growth efficiency (specific growth rate, feed conversion ratio), and water quality using Analysis of Variance ($p < 0.5$; preplanned contrasts: T1 with T2, T2 with T3 and T4; T3 with T4).

Experiment 2. Assess economic and environmental benefits of combining Shing at different densities with Koi-carp pond polyculture.
Null Hypothesis: No differences in growth efficiency, water quality, or economic returns are observed when Shing are polycultured with Koi and carps, regardless of stocking density.

This experiment will assess whether incorporation of Shing into Koi-carp polyculture could provide additional benefits to farmers as the new polyculture technology could provide an additional crop of high nutritional and economic value. Currently, Shing fetch almost 750 BDT/kg ($5/lb.), a price substantially higher than any other cultured seafood in Bangladesh. While Experiment 1 will directly compare semi-intensive polyculture of Koi with carps versus current Koi monoculture practices, we expect that daily reductions in feed ration by 50% will prove the most cost-effective strategy as was seen with Shing-carp polyculture in our previous AquaFish research. In this experiment we will test different stocking densities of Shing in Koi-carp polyculture under the assumption that the 50% reduced feeding and fertilization strategy will be most beneficial (T4 group in Experiment 1). Should this not be the case then we will test Shing culture under conditions that yielded the best net return on investment from the T2-T4 fertilization-feeding strategy in Experiment 1. The following experimental design is proposed:

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Rohu (*L. rohita*)	80 (0.8/m^2)	80 (0.8/m^2)	80 (0.8/m^2)	80 (0.8/m^2)
Catla (*C. catla*)	20 (0.2/m^2)	20 (0.2/m^2)	20 (0.2/m^2)	20 (0.2/m^2)
Koi (*A. testudineus*)	500 (5.0/m^2)	500 (5.0/m^2)	500 (5.0/m^2)	500 (5.0/m^2)
Shing (*H. fossilis*)	0	100 (1.0/m^2)	200 (2.0/m^2)	300 (3.0/m^2)
Fertilization/Feeding Best of T2-T4 – Experiment 1, Assumes T4 is best here	4:1 (N: P), 50% Daily Ration	4:1 (N: P), 50% Daily Ration	4:1 (N: P), 50% Daily Ration	4:1 (N: P), 50% Daily Ration
Replicates (*n*)	4	4	4	4

The treatment groups will be randomly assigned to ponds (N = 12, 100 m^2, 1.5 m depth). The rate of feed applied will be calculated based on that established for Koi in Experiment 1, and the amount applied will be calculated based on the biomass of both Koi and Shing and adjusted every two weeks from fortnightly sampling of fish weights. Shing growth is relatively slow and fish reach marketable sizes at 25-60 g, hence the reason for their high price. Application of the additional feed for production of Shing should therefore have minimal impact on water quality or in reaching pond carrying capacity requiring costly

aeration and water exchange. The preparation of ponds, fertilization rates, and sample collection (growth data, water quality parameters) will be performed as described in Experiment 1. As outlined in Experiment 1, the final production yields (market weight, kg), estimated market return, feed and labor costs will be determined at the end of experiment for an additional cost-benefit analysis by Dr. Sadika Haque (BAU). Treatments will be tested for significant differences in growth (mean length, weight X time), growth efficiency (specific growth rate, feed conversion ratio), and water quality using Analysis of Variance ($p < 0.5$).

Trainings and Deliverables

1. The findings from Experiments 1-2 will be reported through the Technical Reports of the AquaFish Innovation Lab (Final Investigative Report, FIR), and possibly through scientific proceedings of regional and/or World Aquaculture Society meeting. Depending on results, a peer-reviewed paper will likely follow completion of the project.
2. We estimate two-four undergraduate and graduate students will receive training on management strategies related to Shing/Koi culture and reduced feeding strategies in aquaculture.
3. The research outcomes, should they prove effective will also be disseminated through production of an extension factsheet in the local language for wider outreach to farmers, extension agencies of the government, and NGOs.
4. As part of Investigation 5, an estimate of 60 local farmers, extension agents or other stakeholders will receive training on the results and benefits of these studies through two workshops held in the greater Mymensingh area of Bangladesh.

Schedule

July 2016 to February 2017: Conduct Experiment 1 pond trial to evaluate reduced-feeding strategies for koi-carp polyculture; water quality analyses, data tabulation and analyses, write-up of initial report

March 2017 to November 2017: Experiment 2 pond trial evaluating effect of combining Shing at different stocking densities in Koi-carp polyculture; laboratory analyses, data tabulation and analyses, write-up of report.

December 2017 to February 2018: Generate an extension factsheet, write up Final Technical Report for the work and prepare a manuscript.