AQUAFISH INNOVATION LAB

TECHNICAL REPORT
INVESTIGATIONS 2011-2013

FEED THE FUTURE INNOVATION LAB
FOR COLLABORATIVE RESEARCH ON AQUACULTURE & FISHERIES
(AquaFish Innovation Lab)

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AQUAFISH INNOVATION LAB
TECHNICAL REPORTS: INVESTIGATIONS 2011-2013

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Cover Photo

Tilapia served at a restaurant in Honduras. Photo by Tiffany Woods.

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EXPERIMENTAL POND UNIT ASSESSMENT IN BANGLADESH

Production System Design & Best Management Alternatives/Activity/09BMA09NC

FINAL INVESTIGATION REPORT

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ABSTRACT

The purpose of this study was to assess production and water quality parameters in: 1) two freshwater prawn-farming systems in Southwest Bangladesh, 2) prawn-farming ponds in Eastern North Carolina, 3) and tilapia-carp polyculture ponds in Mymensingh region of Bangladesh. In the first study an exploratory survey was conducted to characterize two major prawn farming systems, a modified pond system where rice fields are permanently converted to year-round prawn production and gher (pond) systems where prawn is integrated with rice culture. Studies were conducted for 120 days in the Dumuria, Upazila Province of Khulna District, in Southwest Bangladesh. Freshwater prawn (*Macrobrachium rosenbergii*) was cultured in 8 separated modified ponds allocated to two treatments: prawn culture in modified ponds systems and prawn culture in gher systems. Factorial analysis was run to identify the main ecological processes affecting water quality in the ponds. The Factor1, Factor2, and Factor3 accounted for 37%, 16%, and 13%, respectively, of the overall variability of the data. Factor1 showed the combined effects of rain and liming on the water quality of the ponds/ghers, both of which were elevated at the start of the experiment and then gradually declined at the end. The second factor (Factor2) showed the opposite effects of decomposition and photosynthesis on oxygen and ammonia content of the water. The third factor (Factor3) showed positive correlations among chlorophyll, pH, and dissolved oxygen, which reflected another aspect of photosynthesis related to phytoplankton biomass and oxygen released. The ANOVA model applied accounted for only 23% of the variability of Factor3, half of it caused by

treatment. Phytoplankton biomass and oxygen production were higher in only prawn ponds than in ghers where rice was previously cultured. Mean value (± SD) of soil pH, organic carbon (%), total phosphorus (ppm), and total nitrogen (%) were 7.1 (± 0.30), 1.6 (± 0.3), 15.80 (± 4.8), and 0.15 (± 0.02), respectively, in modified pond systems, and 6.5 (± 0.64), 2.5 (± 1.25), 11.94 (± 3.9), and 0.23 (± 0.11) in gher systems. The mean production of prawn in modified pond and gher culture systems was 407.5 (± 15.55) and 335 (± 19.15) $kg.ha^{-1}$, respectively. Although the prawn production in gher systems was significantly lower ($p < 0.05$), the overall agricultural production, socio-economic, and sustainability benefits may be greater for the gher system since it integrates both rice and prawn production. Potential replenishment of nutrients in bottom mud with prawn culture may also allow for enhanced utilization by rice crops.

The second study experiment evaluated water quality and production parameters using pelleted and powdered fertilizers on prawn growout in experimental ponds in Eastern North Carolina. Prawn farming has become popular in NC and Southeastern United States, particularly for small farmers. An assessment of responses in pond dynamics to different forms of fertilizers could be used for future work aimed at improving management practices both in Bangladesh and the U.S. Four, 0.10-ha earthen ponds were stocked with juvenile *Macrobracium rosenbergii* obtained from a commercial hatchery. A total of 3,000 animals (avg. wt. 0.14 g) were stocked into each pond (30,000/ha) in June at the Tidewater Research Station in Plymouth, NC. One treatment (Pelleted Fertilizer) consisted of a large (4 cm diameter) dense, compact, water stable pellet made from a mixture of grain byproducts. The second treatment (Powdered Fertilizer) used the same ingredient mixture but the pellets were ground to a fine powder form that would pass a #1 brass screen (5 mm x 5 mm). Two of the ponds suffered catastrophic dissolved oxygen (DO) depletion during the production period. One episode was caused by the sudden die-off of submerged plants. The second episode was associated with a severe weather event that caused a rapid mixing of the ponds and resulted in a phytoplankton die-off and dissolved oxygen depletion. Supplemental emergency aeration was provided to both ponds but the DO concentrations remained low for several days. As a result of these die-offs, only one pond in each treatment was harvested. Mean water quality parameters fluctuated during the season but remained within ranges reported for previous studies in production ponds fertilized with organic matter. Prior to the DO depletion events, the water quality between the two treatments was similar and relatively stable. Given the lack of final replication, we will not be able to obtain statistical significance for any of the production variables measured. On a per hectare basis, production equaled 342 and 439 kg/ha and food conversion (wt. feed applied/wt. prawns produced) was 1.7 and 1.4, for the powdered and pelleted fertilizers, respectively.

The aim of the third study was to evaluate water quality and the growth and production of Nile tilapia (*Oreochromis niloticus*) polycultured with Silver carp (*Hypophthalmichthys molitrix*) in ponds under treatments (4 replicate ponds/treatment) of fertilization alone (T_1), feeding alone at 100% ration level (T_3), and fertilization combined with feeding at 50% ration (T_2). The experiment was carried out for 120 days, at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. The recorded range of air temperature was 28-32 ^oC, water temperature 30-34.8 ^oC, transparency 19-65 cm, pH 6.79-10.86, dissolved oxygen 1.75-8.48 mg l^{-1}, total alkalinity 8-152 mg l^{-1}, phosphate-phosphorus 0.08-3.0 mg l^{-1}, nitrate-nitrogen 0.00-0.51 mg l^{-1}, nitrite-nitrogen 0.00-0.26 mg l^{-1}, ammonia-nitrogen 0.14-1.57 mg l^{-1}, TDS 25.6-109 mg l^{-1}, conductivity 55-203 µSc m^{-1} and chlorophyll-*a* 2-250 µg l^{-1}. Temperature, dissolved oxygen, alkalinity, nitrite-nitrogen, phosphate-phosphorus and chlorophyll-a did not vary significantly among the treatments. However, transparency, TDS, and conductivity increased in those treatments where supplementary feed was applied. No significant differences were found in stocking weight and survival (%) for both species. The mean harvesting weight of tilapia was significantly lower in T_1 (fertilization alone) than those of T_2 (fertilization plus 50% supplementary feeds) and T_3 (only feeds) groups, while, for silver carp, the mean harvesting weights did not show significant differences among treatments. Specific growth rate (SGR) for tilapia was lower in T_1 compared with the T_2 and T_3 groups. Tilapia in the T_2 group had a significantly higher SGR than fish in the T_3 group. The feed efficiency (or FCR) was 30% better for tilapia in the T_2 compared to the T_3 treatment. Silver carp

SGR was slightly higher in the T_1 (2.3) versus T_2 (2.2) and T_3 (2.15) groups. The combined FCR for both tilapia and silver carps showed a similar pattern as that calculated for the tilapia FCRs. The gross and net production performances of tilapia were considerably higher in T_2 and T_3 as compared with T_1, whereas treatment did not alter these variables for Silver carp. The combined net production of the two species was significantly higher in T_2 (4227 kgha^{-1}) and T_3 (3845 kgha^{-1}) compared with T_1 (1567 kgha^{-1}). The T_2 group also had the highest benefit-cost ratio suggesting the polyculture of tilapia and Silver carp on combined fertilizer and 50% ration inputs is more economical than that of fishes raised either on fertilizer or feeds alone. Collectively these results suggest that farmers can grow tilapia with silver carp to both diversify their crops and improve their incomes with no loss in harvested biomass when utilizing combined fertilization and supplemental feeding of commercial diets at the 50% ration level.

STUDY 1. CHARACTERIZATION OF FRESHWATER PRAWN FARMING SYSTEMS AND ASSESSMENT OF WATER QUALITY PARAMETERS IN SOUTHWEST BANGLADESH

INTRODUCTION

Freshwater river prawn (*Macrobrachium rosenbergii*, locally known as 'golda') has been predominantly farmed in Southwest Bangladesh and its potential for expansion is favorable due to the wide availability of abundant freshwater ponds, wetlands, and rice-fields. Prawn, as an indigenous species, is widely distributed in the river systems of the Southwest and Southeast regions and estuaries in the Sundarbans mangrove forests (Hoq 2008; Paul 2008).

Around 1978, some local farmers in the Fakirhat area of Bagerhat district began stocking prawn PL in fish ponds on experimental basis (Kendrick 1994). Some innovative farmers developed prawn-farming technology in the low-lying rice fields during mid 1970s–1980s (Rutherford 1994). In the late 1980s, prawn farming practice was widely adopted in the Fakirhat area of Bagerhat district, where prawns were grown along with major carps (rohu, catla, and mrigal) and exotic carps (silver carp, common carp) in rice fields, incorporating a space for refuge of both prawn and fish in the corners of the rice fields (Kamp and Brand 1994). This modified prawn culture system developed in the rice-fields with raised embankment was locally known as 'ghers'. Over the last 30 years different modifications have evolved based on trial and error by the farmers themselves and there has been diversification in both the systems and crops utilized. While ghers constitute 70% of farming systems utilized, some farmers have permanently converted their rice-fields into ponds for year-round growout of prawns with a short interval after harvest to allow pond preparation for the next crop.

Owing to the disease outbreak in marine shrimp farms, prawn culture expanded in the mid 1990s and continued over the decade. Freshwater prawn farming has further developed and progressed in both ghers and pond systems in the Southwest and Southeastern districts of Bangladesh by 15% (Wahab et al. 2012). There are 94,350 prawn producers with an average size farm of 0.58 ha. Small and medium scale farmers play a large role in pond culture of prawns with an average size farm of 0.20 ha in major producing areas in the Southwest region (Nuruzzaman 2010).

The annual yield of prawns in Bangladesh ranged from 375 to 500 kg ha^{-1} in integrated prawn-rice culture systems, and 450–500 kg ha^{-1} in converted pond culture systems developed from fallow rice fields (Khondoker 2008). In 2008–2009, Bangladesh produced 26,138 MT of prawns from different production systems, while 90% of this production (23,597 MT) was from aquaculture in the Southwestern region (DoF 2010; Rahman 2010), the rest coming from river, floodplain, and wetland capture fisheries.

It is recognized that prawn farming is an important aquaculture activity in Bangladesh and plays a significant role in poverty alleviation, employment generation, foreign exchange earnings, and in improving socioeconomic conditions of farmers and rural poor (Ahmed et al. 2008). Despite the growth of prawn farming in Bangladesh, a number of challenges, including production technologies and post-harvest processing and marketing, have caste doubts on its sustainability. One of the major causes of frustration among the farmers is the unpredictable and variable production levels that may result, in some cases leading to farm losses. Farmers traditionally manage their prawn farms through liming, fertilization and occasional feeding; these may have implications on the water quality and environmental factors, which may be responsible for the varying degrees of production in different farming systems. Water quality of aquaculture systems, including physical and chemical parameters, bottom soil, and sludge may cause the slower growth of prawn, which needs to be evaluated through research. There has been no basic information on the water quality vis-à-vis environmental parameters of the prawn farming ghers or ponds located in Southwest Bangladesh. The aim of this study is to characterize two major prawn farming systems in the Southwest region developed over the years and to compare and contrast the water quality and environmental parameters so as to understand the reasons for variable production performance among the culture units and between the production systems.

MATERIALS AND METHODS

Site of the Experiment

The present study was carried out on prawn farms located in the Dumuria Upazila of Khulna District, Southwest Bangladesh. The area is situated at N22º51´31.1´´ to N22º52´18.4´´ latitude and E89º26´14.9´´ to E89º29´04.7´´ longitude. The experiment was conducted during 120 days from July to October 2012. Eight culture ponds 4 without connection with rice fields and 4 ponds connected with rice fields (ghers), were used for this study. The ponds were located at Salua Union and ghers were located at Ramkrisnapur Union, both in Dumuria Upazila, Khulna District. Pretested questionnaires were used for collection of baseline data on the culture practices and pond characteristics. Collection of stocking data and harvest data were also made through repeated visits to the farm sites at stocking and harvesting times.

Analyses of water quality parameters

Water samples were collected fortnightly from each pond using a plastic pipe inserted vertically from surface to near bottom. The integrated water samples were transferred to plastic containers (2L), allowed to stand still in the container for about 5 minutes, and brought to the laboratory. Water quality parameters such as temperature (ºC), alkalinity (mg/l), salinity (ppt), pH, ammonia nitrogen (mg N/l), nitrite nitrogen (mg N/l), total nitrogen (mg N/l), total phosphorus (mg P/l), total suspended solid (mg/l), dissolved oxygen (mg/l), secchi disc depth (cm), and Chlorophyll-A (μg/l) were analyzed using standard methods. Water temperature (thermometer) and pH (colometric test, Hach Kit, Model-FF-3) were recorded directly from ponds. For dissolved oxygen estimation, water samples were carefully collected in labeled BOD bottles (125 ml) without entrapment of water bubbles. Dissolved Oxygen (DO) and alkalinity were measured by titration using a Hach kit (model FF-3). Ammonia nitrogen and nitrite nitrogen were also determined through colorimetric tests. The measurements of total dissolved solids (TDS), total nitrogen, and total phosphorus were carried out with a Hach kit (DR/2000, direct reading spectrophotometer). Salinity was measured by salinity refractometer (ATAGO S/Mill-E), and water transparency was determined using a Secchi disc. Chlorophyll-A was analyzed following GF/C glass fiber filtration and acetone extraction (Clesceri and Franson, 1998) using the spectrophotometry method. The evaporation rate was simply measured with an evaporation pan and pond depth was measured at the deepest point of the pond.

Collection and analyses of bottom soil samples

Soil was collected twice (prior to stocking and at the time of the last water sampling) from all ponds. Soil samples kept in separate labeled polyethylene bags, brought to the laboratory and stored prior to analysis. Parameters analyzed in the laboratory condition were pH, texture, organic carbon (%), total phosphorus (ppm), and total nitrogen (%).

Statistical Analysis

Water quality data was recorded, summarized, and analyzed using Microsoft Excel 2007 and PASW Statistics 18 (Predictive Analytics Software, formerly named SPSS) (Field 2009). One-way analysis of variance (ANOVA) and Duncan's Multiple Range Test were used to determine differences between treatment means at a significance level of $P < 0.05$. Ecological processes that account for the main variability of the measured variables were identified through factorial analysis (Kim and Mueller 1978; Milstein 1993). Factorial analysis is a multivariate exploratory technique that allows an assessment of relationships among a set of variables in terms of a limited number of new variables, which are assumed to be responsible for the covariation among the observed variables. From the several available techniques to extract factors, principal components (Seal 1964; Jeffers 1978) calculated from the correlation matrix among variables were used here. The first factor extracted from that matrix is the linear combination of the original variables that accounts for as much of the variation contained in the samples as possible. The second factor is the second linear function of the original variables that accounts for most of the remaining variability, and so on. The factors are independent of one another, have no units, and are standardized variables (normal distribution, mean=0, variance=1). The coefficients of the linear functions defining the factors are used to interpret their meaning, incorporating the sign and relative size of the coefficients as an indication of the weight to be placed upon each variable. One-way ANOVA and Duncan tests were applied to test the effect of treatment (with or without rice culture in the prawn ponds) on each factor extracted. These analyses were carried out using the Statistical Analysis System program (SAS 2000).

RESULTS

Prawn culture in pond systems

The pond systems were rectangular shaped, had an average depth of 1.5 m, and a surface area ranging from 0.4 ha to 1 ha. In this culture system, the main water sources were rainfall and ground water. Prior to starting culture, all ponds were dried completely for two weeks, tilled by tractor, limed at 250 kg ha^{-1}, treated with rotenone (2.5 kg ha^{-1}) for controlling undesirable species, and filled with rain water during mid June. Hatchery-produced post larvae prawns (5 mm length) were stocked at a low density (20,000 ha^{-1}) typical of that in the Khulna Area. No fertilizer was provided for pond culture systems. Both processed and farm-made supplementary prawn feed was used in this culture system. Small-size processed feed (CP feed, Thailand; and Mega starter, Bangladesh; feed containing 40% crude protein) was used during the first month, and medium-size feed (CP feed, Mega grower containing 30% crude protein) was used during the rest of the culture period. Some homemade (prepared from snail, rice bran, wheat bran, daal) supplementary feed was also used. Prawns were fed twice daily, via a feeding tray placed at the corner of each pond, during early morning and evening. Major harvest of prawns started after 5-6 months of stocking in November to December. Partial harvesting was continued up to April-May of the following year. The average prawn size at harvest was 60-150 g, with larger sizes found during the major harvest.

Prawn culture in "ghers" systems

In the Khulna region, freshwater ponds are mostly cultured in modified rice fields, referred to as the "gher" system. Gher is developed through building higher dikes around the rice fields and excavating a canal inside the periphery to retain water during the dry season. In this culture system, the selected four ghers ranged from 0.4 ha to 6.8 ha with depths ranging from 1.5 to 2.0 m. Prior to culture, modified rice ponds were completely dried, tilled by tractor, and limed at 250 kg ha^{-1}. Farmers used phostoxin tablets, geolite, and bleaching powder as preparatory measures for controlling undesirable fish species. The principal water sources of the ghers are rainfall, ground water pumped as needed, and canals connected with nearby water-bodies. During the rainy season (July-October) the entire gher was inundated and used for cultivation of prawns. However, in the dry season (January – May), farmers cultivate boro rice in the central plateau of the gher, with the trenches holding prawn as refuge. In these gher systems, farmers stocked PL prawn at 25,000 ha^{-1} (8 mm length) during mid June to early July. Ghers were fertilized with urea (25 kg ha^{-1}), triple super phosphate (13 kg ha^{-1}), and mustard oil cake at the standard rate usually applied in the region. Prawns were fed farm made feeds consisting of a mixture of fishmeal, rice bran, mustard oil cake, mollusks, and wheat flour. They also used commercial feed (Mega starter, Mega grower, Quality feed, Bangladesh feed, containing 30-35% crude protein). Adult prawns were harvested primarily from November to January, after a culture period of around 6 months. The average size of prawn at harvest was from 50-120 g.

Assessment of Water Quality using Multivariate analysis

Factorial analyses were run to identify the main ecological processes affecting water quality in the ponds. Total nitrogen, total phosphorus, and total dissolved solids were not included in the factor analysis because each of these variables has several components with different ecological behavior, which makes it difficult to or can compromise interpretation. Table 3 presents the results of the factorial analysis and ANOVA on the extracted factors performed. Three factors were identified, which together accounted for 63% of the overall variability of the data. The ANOVA models of the three extracted factors showed no significant treatment by date interaction, so an ANOVA testing only for main effects was run and is herein presented.

The first factor (Factor1) accounted for 37% of the overall variability of the data. It is a bipolar factor, with water depth and transparency positively correlated between them; salinity, alkalinity, and nitrite positively correlated among them; and both variable groups negatively correlated between them. It shows the combined effects of rain and liming on the water quality of the ponds/ghers, both starting together at the beginning of the experiment and with decreased effects by the end of the experiment. Rain accounts for the negative correlation between water depth and salinity and the positive correlation between water depth and transparency. Rain increases water level in the ponds/ghers, diluting salts and resuspending particles that decrease water transparency. Liming accounts for the positive correlation between alkalinity and nitrite. Liming increases the alkalinity of the water and promotes decomposition of organic matter accumulated on the bottom, which liberates ammonium into the water. Nitrifying bacteria transform ammonium first into nitrite (*Nitrosomonas*) and then into nitrate (*Nitrobacter*), decreasing ammonium and increasing oxygenated nitrogen forms in the water. However, *Nitrosomonas* develop faster than *Nitrobacter* so that prior to the establishment of both nitrification steps, nitrite may accumulate in the water (e.g. Avnimelech et al., 1986; Azov & Tregubova 1995; Prinsloo et al., 1999). *Nitrobacter* is more inhibited by water mixing (Azov & Tregubova 1995) than *Nitrosomonas*, which increases the nitrite accumulation effect during the rainy period when rain mixed water and resuspended particles decreased water transparency. The ANOVA model applied accounted for 90% of the variability of Factor1, almost all due to date. Factor 1 started with high values after the pond preparation with liming and PL stocking. It decreased during the rainy period (Jul-Aug) as rain increased water level and turbidity and decreased salinity, and only when the second step of nitrification was established did nitrite levels decrease. From mid September onward there was no rain, so water depth and transparency stayed at their highest levels and salinity, alkalinity, and nitrite at their lowest levels. The treatment main effect indicates that Factor1 was higher in the ponds where rice was previously cultured.

The second factor (Factor2) accounted for a further 16% of the overall variability of the data. It is a bipolar factor, with ammonium negatively correlated with dissolved oxygen. It shows the opposite effects of decomposition and photosynthesis on oxygen and ammonium content of the water. Through decomposition, oxygen is consumed and ammonium is released into the water, while through photosynthesis, ammonium is absorbed and oxygen is released into the water. High Factor2 values indicate dominance of decomposition and/or low photosynthesis, while low Factor2 values indicate dominance of photosynthesis and/or low decomposition. The ANOVA model applied accounted for 61% of the variability of Factor2, most of all due to date and only 5% due to treatment. After pond preparation and before PL stocking decomposition was low and photosynthesis was high. Intensity of decomposition increased during July, was maximum in August when the highest water temperatures were recorded (31-

32°C *vs.* 29-30°C in the other months), and stabilized in an intermediate level until the end of the sampling period. By contrast, photosynthesis decreased during the rainy period when light was limited by cloudiness and mixed water, and stabilized at a higher level when rain stopped and sunshine and calm waters were enhanced and ammonium absorption increased. Photosynthesis was higher in the ponds in which rice was previously cultured since they received fertilizers during pond preparation, and decomposition was higher in only-prawn ponds. The mild differences between treatments were most evident in July and August relative to September and October.

The third factor (Factor3) accounted for a further 13% of the overall variability of the data. It shows positive correlations among chlorophyll, pH, and dissolved oxygen, which reflects another aspect of photosynthesis, this time related to phytoplankton biomass and oxygen release. The ANOVA model applied accounted for only 23% of the variability of Factor3, half of it due to treatment and the other half being insignificant. Phytoplankton biomass and oxygen production were higher in only prawn ponds than in ponds where rice was previously cultured.

<u>Analyses of Soil Samples</u>

Soil was collected twice (prior to stocking and at the time of the last water sampling) from all the ponds as shown in Table 4. The textures of soil were silt loam and silt clay loam in modified pond culture systems, whereas in gher systems, clay, silt loam, silt clay, and silt clay loam were the main soil constituents. Available soil pH was observed from four ponds of each treatment. The mean soil pH was recorded 7.1 ± 0.30 in pond culture. In this system, available pH in sediment was found to be lowest (6.5) in early July and highest (7.5) in the month of October. The mean soil pH was 6.5 ± 0.64 in gher culture systems. In this system, lowest pH was 5.4 and highest was 7.0 in the month of October. The mean soil organic carbon content was 1.6 ± 0.3 % in pond systems with the lowest and highest values at 1.0 and 1.9%, respectively. The mean soil organic carbon content was found 2.5 ± 1.25 % in gher systems. In this system, the lowest organic carbon was observed (1.3%) in early July and the highest (4.5%) at the end of October. The mean soil available phosphorus levels were 15.80 ± 4.8 ppm in pond systems. In gher systems, on the other hand, the mean soil phosphorus level was 11.94 ± 3.9 ppm. The mean total nitrogen in sediment was 0.15 ± 0.02 % and 0.23 ± 0.11 % in pond and gher systems, respectively.

<u>Prawn Production in Gher and Pond Systems</u>

Table 5 showed that the average prawn production from the pond culture systems was 407.5 ± 15.55 kg/ha and that from gher system was 335 ± 19.15 kg/ha. The production of rice and fruits/vegetables has yet to be collected for understanding the overall benefit of the gher system.

DISCUSSION

<u>Characterization of farming system: Farmers innovation and rationale</u>

Two types of farming systems, one in the modified pond and the other in gher systems, have evolved in the Southwest greater Khulna region of Bangladesh. In pond systems, prawns are cultured for longer periods with a short dry season for pond preparation and re-excavation. In gher systems, rice is farmed and after harvest the entire field is inundated with water for prawn growout. Gher prawn culture is only done for one season from June/July to November/December, while ponds are used for the whole year from June to May.

<u>Multivariate analysis of water quality</u>

The observed values of the variables are the result of different processes that occur simultaneously in the ponds. Since the water samples integrate water from the entire water column, the values observed are affected by processes acting at the surface and bottom. For example, the observed oxygen content of the water sample is affected by photosynthesis occurring in the surface layers and by decomposition occurring mainly in the bottom layers. Factor analysis, a multivariate method based on correlations among variables, allowed identification of the main ecological processes affecting water quality in the ponds.

Water quality variability with time

Figure 1 presents the tridimensional plot of the three factors extracted, showing time variability. In July, after liming and with the start of rains, salinity and alkalinity were high and water depth and transparency low (Factor1 high) with high photosynthesis and low decomposition (Factor2 low). Phytoplankton biomass (Factor3) presented a wide range of values among ponds (most July points in the upper right section of the figure, from front to back). With time the effects of liming decreased, those of rain accumulation increased, nitrification and decomposition of organic matter developed, but cloudy weather and still turbid waters did not allow phytoplankton biomass and photosynthesis to increase. Thus, in August, Factor1 values were still high but lower than in July, Factor2 strongly moved towards increased ammonium release due to decomposition, and Factor3 concentrated more into the mid-value range (most August points in the mid-height left mid-depth section of the figure). When rain stopped phytoplankton biomass did not change much (Factor3 continued in mid values) but photosynthesis was more efficient (Factor2 moved right), so that most September-October points are down and in the center of the Factor2*Factor3 surface.

Water quality variability between treatments

Variability between treatments was very small as compared to the variability in time due to rain, and was related to different management procedures, as expected. The differences in Factor1 between treatments seem to be related to water depth, which were deeper in ponds where prawns only are grown. The prawn ponds are relatively deeper than the ghers as the latter are used for rice farming, therefore maintained at a lower depth. The trenches in the ghers, however, are of similar depths of the prawn ponds.

Differences in Factor2 between treatments were related to the previous history of the ponds. Before the experiment, the ponds were used either for rice or for prawn culture. In June, all ponds were tilled and prepared for the new prawn culture season. This action mixed organic matter remaining from the previous cultures with the soil of the pond bottom. Since organic matter accumulated in prawn culture is more readily degradable than rice straw, decomposition was more pronounced in ponds where only prawns are grown (more positive Factor2 values). Together with this, photosynthesis in rice ponds was enhanced by fertilization at pond preparation time (more negative Factor2 values), a procedure that was not applied to prawn ponds.

Differences in Factor 3 between treatments were related to differences in prawn stocking density and not to the previous rice or prawn culture in the ponds. Prawn stocking density was 17% lower in ponds relative to gher systems. The lower prawn density exerted lower grazing pressure on the phytoplankton, leading to higher chlorophyll and oxygen production than in the other ponds.

CONCLUSIONS AND RECOMMENDATIONS

- Most of the water quality variability observed in this study occurred over time, related to the effects of heavy rains at the beginning of the culture period. Only a small part of the variability was due to treatment, linked to management procedures.
- The production of prawns in gher systems was significantly lower than that of the modified pond culture system.
- However, the overall socio-economic benefits and sustainability may be enhanced in the gher culture system that integrates both rice and prawn for ensuring food security for the farming households.
- Increased utilization of nutrient sinks in the bottom mud allows for better replenishment of gher culture systems.

- Bottom mud of pond systems, and of gher systems to a lesser extent, may be utilized for dyke cropping of seasonal vegetables as well as short duration fruit crops.
- Further research on the potential for integrating prawns that are destined for export, with finfishes and with dyke cropping can enhance domestic consumption of protein and micronutrients for improving nutritional security of households.

STUDY 2: EXPERIMENTAL POND ASSESSMENT FOR PRAWN CULTURE IN EASTERN NORTH CAROLINA

This experiment evaluated water quality and production parameters using pelleted and powdered fertilizers on prawn growout in experimental ponds in Eastern North Carolina. Prawn farming has become popular in NC and Southeastern United States, particularly for small farmers. We evaluated water quality and production parameters of prawn grown in ponds with application of pelleted and powdered fertilizers, both to assess responses in pond dynamics that could be used for future work aimed at improving management practices both in Bangladesh and the U.S.

MATERIALS AND METHODS

Four, 0.10-ha earthen ponds were stocked with juvenile *Macrobracium rosenbergii* obtained from a commercial hatchery. A total of 3,000 animals (avg. wt. 0.14 g) were stocked into each pond (30,000/ha) in June at the Tidewater Research Station in Plymouth, NC. The ponds received feed and fertilizer inputs according to protocols established for the management of the ponds. A variety of physical and chemical analyses were performed on all the ponds (Egna et al. 1987; APHA et al. 2012).

Two organic fertilizer treatments were evaluated to determine their effects on water quality dynamics and production variables. One treatment (Pelleted Fertilizer) consisted of a large (4 cm diameter), dense, compact, water stable pellet made from a mixture of grain byproducts. The second treatment (Powdered Fertilizer) used the same ingredient mixture but the pellets were ground to a fine powder form that would pass a #1 brass screen (5 mm x 5 mm). Our hypothesis was that the higher surface area of the ingredients in the Powdered Fertilizer treatment would result in more rapid breakdown of the ingredients and lead to greater daily fluctuations in water quality variables. The ponds were harvested in September after a 104-day culture period. Total prawn production was determined and average weights were calculated to estimate survival. Due to a limited availability of ponds and larvae, only 2 ponds per treatment were stocked.

RESULTS AND DISCUSSION

Two of the ponds (nos. 11 and 14; Table 6) suffered catastrophic dissolved oxygen (DO) depletion during the production period. One episode was caused by the sudden die-off of submerged plants. The second episode was associated with a severe weather event that caused a rapid mixing of the ponds and resulted in a phytoplankton die-off and dissolved oxygen depletion. Supplemental emergency aeration was provided to both ponds but the DO concentrations remained low for several days. As a result of these die-offs, only one pond in each treatment was harvested. Given the lack of final replication, we will not be able to obtain statistical significance for any of the production variables measured. However, several observations about the water quality dynamics and the hydrologic variables can be made based on the collected data.

Mean water quality parameters fluctuated during the season but remained within ranges reported for previous studies (reviewed by Boyd 1990) in production ponds fertilized with organic matter (Table 7).

Prior to the DO depletion events, the water quality between the two treatments was similar and relatively stable. Phosphorus values are several times higher than those normally reported in the literature. Based on our 20 years of experience with these ponds and with the water source (Castle Hayne aquifer with high hardness), these phosphorus concentrations are typical and furthermore do not appear to indicate excessive fertilization. Indeed, the phosphorus levels remain high throughout the production period but do not contribute to phytoplankton production. Chlorophyll-α and Secchi disk values remained at relatively moderate and stable levels in all ponds throughout the summer months, despite the presence of high amounts of orthophosphate. We have hypothesized that the phosphorus analysis itself (ascorbic acid method) is detecting different chemical forms of phosphorus that are non-reactive, which leads to artificially high measured levels.

Final production and mean harvest weight of prawns are within values cited in the literature for heavily fertilized earthen ponds (Table 8; D'Abramo et al. 2009). On a per hectare basis, production equals 342 and 439 kg/ha. Food conversion (wt. feed applied/wt. prawns produced) is 1.7 and 1.4, respectively.

The physical characteristics of the ponds, including the evaporation and seepage values, were determined for the four ponds during the production period (Table 9). All four ponds were constructed at the same time and were very similar in dimension (surface area and depth). Evaporation values were determined from published pan evaporation rates provided by National Weather Service automated station located within 1 km of the ponds. Evaporation values are slightly higher than those reported for many other aquaculture ponds. Wind velocity in the area where the ponds are located is relatively high and constant, which contributes to elevated evaporation rates. Mean seepage values were determined in several ponds during the course of the production period. These values are relatively low and within other published values for earthen ponds constructed on coastal plain soils.

Twenty-four hour sampling of the ponds revealed very little stratification of the water column during the first month (June; Figure 2) of the production cycle when the ambient daytime temperatures were lower and the phytoplankton abundance was also relatively low (Table 6). Thermal stratification was very evident in September (Figure 2) when air temperatures were much higher and phytoplankton abundance was greater, which prevents light penetration to the lower levels of the water column.

SUMMARY

Statistical comparisons between treatments were complicated by the catastrophic die-off and subsequent DO depletion in two ponds. However, water quality, production, and hydrologic variables were similar to those reported in the literature for heavily fertilized earthen ponds used for freshwater prawn production. Future studies should incorporate a higher number of replicates to increase the power of statistical comparison according to the variation inherent in water quality and production data.

STUDY 3. ASSESSMENT OF WATER QUALITY AND PRODUCTION POTENTIALS OF EXPERIMENTAL POND UNITS FOR THE POLYCULTURE OF TILAPIA AND SILVER CARP IN BANGLADESH

INTRODUCTION

Polyculture is a system in which species with distinct feeding niches are used in different proportions within the same pond to improve utilization of natural pond organisms and external feed inputs for better fish production (Jhingran 1995). Inland aquaculture in Bangladesh mainly consists of three Indian major carps and two/three Chinese carps grown in polyculture systems. The culture system is mostly fertilized and supplementary fed with rice bran and oil cake. The exotic Silver carp (*Hypophthalmichthys molitrix*) is an important candidate species in polyculture systems in Bangladesh (Kadir et al. 2007). It is a filter feeding omnivore that prefers natural food organisms enhanced through fertilizers or supplementary feed inputs provided to ponds. The culture of Nile tilapia (*Oreochromis niloticus*) has recently emerged in Bangladesh and is now the 2nd most abundant cultivar outside of carps. This species is largely monocultured in ponds with the use of significant feed inputs alone. Tilapia can be grown in mono and polyculture systems and evidence suggests the latter practice gives higher production than that of monoculture (Khouraiba et al. 1991). However, a full assessment of utilization of carp in tilapia culture has yet to be tested in Bangladesh under semi-intensive conditions whereby fertilizer and supplementary feeds are used in culture. Fertilizers are 10-15% the cost of feeds and their utilization is strongly correlated to enhanced growth of fish due to improved phytoplankton and zooplankton productivity (Abbas and Hafeez-Ur-Rehman, 2005) that can be utilized by both tilapia and carp. The use of fertilizers along with supplementary feed also improves soil fertility as well as increase pond productivity (Batterson 1994; Diana et al. 1996; Feng et al. 2005; Goyal et al. 2005). Tilapia tend to concentrate their feeding activity on supplemental feed, while silver carp utilizes natural productivity enhanced through fertilizer (Almazan and Boyd 1978; Egna and Boyd 1997; Lin 1997). Therefore, higher pond yields may be attained through application of fertilizer and feed in tilapia and silver carp polyculture. Studies show that tilapia monoculture is more efficient under a pond management practice that incorporates fertilization combined with 50% satiation feeding with commercial diet than that with fertilization alone or feeding a commercial diet at 100% satiation alone (Diana et al. 1994). Whether a similar efficiency can be attained when tilapia are polycultured with silver carp is unknown.

The aim of this study was to assess water quality, fish production, and economics of tilapia and silver carp polyculture in ponds under different management strategies that incorporate fertilization alone, full ration feeding alone, and a combination of fertilization and feeding at 50% ration level.

MATERIALS AND METHODS

Experimental site and design

The present study was conducted for 120 days at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. The fish species Nile tilapia (*Oreochromis niloticus*) and Silver carp (*Hypophthalmichthys molitrix*) were stocked in 12 ponds in a completely randomized design allocated to three treatments (see table below): T_1) fertilization alone (Urea 60 kg ha^{-1} and TSP 35 kg ha^{-1} per week), T_2) fertilization and supplementary feeding (Urea 60 kg ha^{-1} and TSP 35 kg ha^{-1} per week plus commercial pelleted tilapia feed daily at half the ration typically applied to commercial production), and T_3) feeding alone daily at the full ration typically applied to commercial production in Bangladesh (20% down to 5% of body weight).

Treatments/Factors	Treatment 1	Treatment 2	Treatment 3
Stocking			
Tilapia	200	200	200
Silver carp	25	25	25
Fertilization/feeding	Fertilization alone	Fertilization + 50% Feed	100% Feed alone

Each earthen pond had an area of 2.5 acres (100 m^2) and depth of 1.0 m. The depth was maintained at 1.0 m during the experiment. Prior to the experiment, all ponds were completely dried for two weeks. Lime was applied at 0.025 kg m^{-2}. Four days after liming, the ponds were filled in with water from an adjacent deep tube-well. All ponds were fertilized initially with urea and triple super phosphate (TSP) at the rates of 60 kg ha^{-1} and TSP 35 kg ha^{-1}, respectively. The fertilization rate is similar to that previously reported whereby the efficiency of tilapia in monoculture is greatest with combined fertilization and 50% satiation feeding than with either fertilization alone or feeding to satiation alone (Diana et al. 1994). After this, urea and TSP were mixed together and applied weekly to ponds for the appropriate treatment groups by spreading. Tilapia (5.39 ± 0.13 cm length and 3.0 ± 0.18 g weight) and silver carp fingerlings (14.03 ± 0.26 cm length and 18.2 ± 1.18 g weight) were stocked 2 weeks later with 200 tilapia (2 tilapia m^{-2}) and 25 silver carp (0.25 carp m^{-2}) respectively. Only commercial pelleted tilapia feed (non floating; 30% crude protein and 5% fat; Mega feed, Bangladesh) was used twice daily (at 07:00 am and 18:00 pm). Following stocking, fish were fed the full ration amount (treatment-3, T_3) at a rate of 20% of body weight (BW) for 30 days, then 15% BW for 30 days (through 60 days post-stocking), 10% BW for 30 days (through 90 days post-stocking), and 5% body weight until harvest. This feeding rate follows that typically being used by tilapia farms in Bangladesh. In treatment-2 (T_2), feed was used at half of the estimated daily feeding rate as that used for T_3, i.e., 10% after stocking for 30 days, reduced to 7.5% from day 30-60 post-stocking, 5% from 60-90 days post-stocking, and 2.5% until harvest. Monthly sampling was made to assess growth (20 fishes of each species of tilapia and silver carp) and to adjust the feeding rate. Weights and lengths of 20 randomly chosen fishes of each species were determined during monthly sampling. At the end of the experiment, fish were harvested by repeated netting using a seine net and then by de-watering the ponds using low-lift pump. Total number and average weight of tilapia and carp was used to assess total biomass of fish at harvest. Mean weight gain (mean final weight - mean initial weight), total weight gain (total harvest weight - total stock weight), specific growth rate (SGR= $[(\ln weight_f - \ln weight_i)/(time_f - time_i)] \times 100$), and feed conversion ratio (feed consumed/body weight gain), and survivorship were calculated for the experiment.

Analyses of water quality parameters

Water samples were collected weekly from all ponds in 250 ml plastic bottles. Integrated samples were collected covering vertical layers of the water column (using vertical haul of the tube sampler covering about 3-4 feet depth). Water temperature was recorded with a Celsius thermometer. Transparency was measured with a Secchi disc of 20 cm diameter. Dissolved oxygen and pH were measured by a portable multi-parameter meter (HACH sension^{tm} 156). The total alkalinity, nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N), total dissolved solid (TDS), conductivity, and phosphate-phosphorus (PO_4-P) were determined using HACH Kit (DR - 4000, a direct reading spectrophotometer). Chlorophyll-A was analyzed spectrophotometrically following GF/C glass fiber filtration and acetone extraction (Clesceri and Franson 1998).

Cost-benefit analysis

An economic analysis of different treatments was performed on the basis of expenditure incurred and the total estimated return from the selling price of tilapia and silver carp. All input costs were recorded. The net benefit was calculated using the following formula: Net benefit = total sale - total investment. Benefit-cost ratio was calculated as total returns ÷ total investment.

Statistical Analysis

Water quality data were recorded, summarized, and analyzed using Microsoft Excel 2007 and PASW Statistics 18 (Predictive Analytics Software, formerly named SPSS) (Field 2009). One-way analysis of variance (ANOVA) and Tukey's multicomparison test were used to determine differences between treatment means at a significance level of $P < 0.05$.

RESULTS

Environmental parameters

Table 9 and Figures 3-15 presents mean water quality data among treatments over the course of the experiment. Air temperature, water temperature, DO, alkalinity, nitrite-nitrogen, phosphate-phosphorus, and chlorophyll-a did not vary significantly among the treatments. However, transparency, TDS, and conductivity varied significantly among the treatments, with higher values seen with full feeding and intermediate values with combined feeding and fertilization. The pH, nitrate-nitrogen, and ammonia-nitrogen were marginally significant among the groups. TDS increased during the first month with initial development of the ecological system, and then moderate as optimum temperature allowed greater decomposition rates. Conductivity presented a rather similar pattern. The patterns of ammonia, nitrite, and nitrate were affected by liming (performed before fish stocking) with increasing values after each application that subsequently decreased thereafter. The temperature remained relatively constant showing some decrease at the end of July and into early August due to heavy rains. Oxygen was generally high, around 6 mgl^{-1} during stocking and about 4.5 to 5.0 mg l^{-1} thereafter.

Growth and production performance of tilapia and Silver carp

Growth, survival, and production performance of tilapia and silver carp are shown in Table 10 and Figures 16 and 17. Initial stocking weight was similar in all groups for both species. The mean harvesting weight of tilapia was significantly lower in T_1 (fertilizer alone) than those of T_2 (fertilizer + 50% supplementary feed) and T_3 (only supplementary feed at 100% ration level). There were no significant differences in mean harvest weight for silver carp among treatments. Survival for silver carp (92-100%) and tilapia (81-89%) was high and did not differ among the treatment groups. Specific growth rate (SGR) for both tilapia and silver carp varied significantly among three treatments, being highest in the T_2 and T_3 groups for tilapia (22-23% increase over T_1 group). Feed conversion ratio (FCR) for tilapia was significantly lower (greater feed efficiency) in the T_2 compared with the T_3 group. Combined FCR (for both tilapia and silver carps) presented rather similar pattern. The gross and net production performances of tilapia were considerably higher in T_2 and T_3 as compared with T_1, whereas, no difference in this parameter was seen for silver carp among the treatments. The combined net production of two species was significantly higher in T_2 (4227 $kgha^{-1}$) and T_3 (3845 $kgha^{-1}$) relative to the T_1 (1567 $kgha^{-1}$) treatment.

Cost-benefit analysis

The results of benefit-cost analysis are shown in Table 11. The major variable input costs were mainly due to supplemental feed. Seed also accounted for considerable portion of input costs. The total investment was slightly higher in T_3 than in T_2, and both these groups had greater input due to feed costs relative to the T_1 group. The highest net benefit was estimated in T_2, followed by T_3 and T_1, respectively. Treatment two (T_2) showed a significantly higher benefit-cost ratio than T_1, but not with T_3.

DISCUSSION

The ponds used in the experiment were similar in size, shape, depth and source of water. Temperature, dissolved oxygen, alkalinity, nitrite-nitrogen, phosphate-phosphorus, and chlorophyll-a did not vary significantly among the treatments. Nitrate-nitrogen, pH, and ammonia-nitrogen were marginally significant, while transparency, TDS, and conductivity were higher in groups that were fed commercial diets with or without fertilization, and lowest where fertilization was used alone. Nevertheless, the water quality parameters recorded in treatments T_1, T_2, and T_3 were found within the suitable range of fish culture.

Water transparency grossly indicates the presence or absence of natural food particles as well as productivity of a water body. Wahab et al. (1995) suggested that the transparency of productive water should be 40 cm or less. During the study period, water transparency ranged from 19 to 65 cm, which was similar with the findings of Kohinoor et al. (2001) in polyculture of small indigenous fishes. In ponds in Thailand that received little fertilization, Secchi disc depth (SDD) averaged 50 cm for most of a fish grow out period (Diana et al. 1987), however, in Panama (Hughes et al. 1991), Indonesia (McNabb et al. 1988), and Rwanda (Hanson et al. 1989), SDD averaged 20 to 30 cm in lightly fertilized ponds. It would appear that productivity was less depleted in ponds where fertilization was used alone than that of ponds where commercial feed was applied.

Water temperature is one of the most important water quality parameters that influences growth, food intake, reproduction, and other biological activities of aquatic organisms. In addition to seasonal effects (Egna and Boyd 1997), water temperature can also exhibit vertical stratification in shallow tropical ponds. Diana et al. (1991a) found 3 to 5 ºC differences in temperature from the top to the bottom of the pond water column in Thailand. In the current experiment, water temperature fell within the suitable range (30 to 34.8ºC) for both tilapia and carp in the three treatments. pH is considered as an important factor in fish culture and is treated as the productivity index of a water body. The mean values of pH in the present experiment were 8.95, 8.70, and 8.50 in T_1, T_2, and T_3 treatments, respectively, which are well within the range found for pond culture practices in Bangladesh.

Dissolved oxygen concentration is one of the vital water quality parameters in aquaculture. Over the course of a day, oxygen levels can change even more dramatically than temperature. Diana et al. (1991b) showed oxygen variations of up to 10 mg l^{-1} from daytime lows to highs for surface waters of ponds in Thailand. The mean values of oxygen concentration in the present experiment were 5.35 (±0.12) mgl^{-1}, 5.32 (±0.19) mgl^{-1} and 5.22 (±0.15) mgl^{-1} in the T_1, T_2, and T_3 treatments, respectively. The concentration of dissolved oxygen in the experimental ponds ranged from 1.75 to 8.48 mgl^{-1}. Boyd (1990) showed that alkalinity below 30 mgl^{-1} as $CaCo_3$ limits primary production in well-fertilized ponds, while in unfertilized ponds alkalinities below 120 mg l^{-1} can reduce primary production. In another experiment, total alkalinity values ranged from 19.0 to 155 mg l^{-1} (Chowdhury et al., 2000). Total alkalinity in the present study ranged from 8 to 152 mg l^{-1} indicating a suitable range for fish culture. There were no differences in alkalinity among the three treatments, which averaged between 91.95 and 95.57 in the present investigation.

The availability of nitrogen is important to primary productivity in fish ponds. Inorganic nitrogen in ponds exists mainly as nitrate, nitrite, ammonia, and ammonium. The presence of different forms of nitrogen is affected by pH, oxygen concentration, and organisms that may produce or consume certain forms of nitrogen (Boyd 1990). Considering nitrogen as a nutrient, algal cells generally take in nitrogen as nitrate, although ammonia may also be utilized by phytoplankton (Knud-Hansen et al. 1991). In order to maintain high levels of primary production, nutrients must be provided in relationship to the needs of plankton and to supplies available from allochthonous sources. CRSP fertilization experiments have documented nitrogen limitation when ponds were fertilized with chicken manure at high inputs (Diana et al, 1991b; Knud-Hansen et al. 1993, Teichert-Coddington et al. 1992). CRSP fertilization experiments to date demonstrate that high rates of primary production occur when N and P are both provided as inputs, usually at rate of 4N:1P (by mass) and a total application of 28kg N and 7 kg P per hectare per week (Knud-Hansen and Batterson 1994). The availability of phosphate-phosphorus is essential for phytoplankton, the primary producer of waters. In the present experiment, the phosphate-phosphorous (PO_4-P) concentration ranged from 0.08 to 3.0 mgl^{-1}. In Bangladesh aquaculture ponds, Uddin (2002) and Rahman (2005) recorded phosphate-phosphorus values of 0.03 to 4.46 mg l^{-1} and 0.21 to 4.0 mg l^{-1}, which encompasses the range observed here for tilapia and Silver carp polyculture. Chlorophyll-*a* (μgl^{-1}) is the indicator of pond productivity, which shows an inverse relationship with water transparency. In the present experiment, the mean (± SE) values of chlorophyll-*a* were 63.4 (±6.39) μgl^{-1}, 72.11 (±6.95) μgl^{-1}, and 74.31 (±5.68) μgl^{-1} in T_1, T_2, and T_3 treatments.

The growth rate of tilapia was comparatively low in T_1 (fertilization only) than those of T_2 (fertilizer plus 50% supplementary feed) and T_3 (only supplementary feed at 100% ration level). The mean harvesting weights of silver carp were 286.08g (±19.59), 254.25g (±15.82), and 240.25 (±10.34) in T_1, T_2, and T_3, respectively, which falls within the range of previous studies where mean weight ranged from 189.9 to 280.35 g (Ahmed 2005).

In the1980s, fish yields obtained from manure-fertilized ponds were reported to range from 7 to 36 kg ha/d (2,555 to 13,140 kg/ha/yr) (Buck et al. 1979; Wolhfarth et al. 1980; Barash et al. 1982; Wolhforth and Hulata 1987). Almost all the high yield ponds (> 30 kg/ha/d) in those reports were polycultured with tilapia and Chinese carps, where both common and silver carps accounted for a large portion of the total yields. In the 1990s, semi-intensive culture of tilapia has gradually gained popularity in developing tropical countries. The yields of tilapia monoculture from manured ponds ranged from 8.6 to 19.2 kg/ha/d (Diana et al. 1991; Green et al. 1994). These yields were comparatively lower than those of Israeli polyculture (20 kg/ha/d) systems (Milstein et al., 1991). In the 2000s, in Bangladesh, Fatema (2004), Uddin (2007), and Rahman (2005) obtained tilapia production in periphyton-based, prawn polyculture systems that ranged from 2711.6 kg ha^{-1} to 3,523.3 kg ha^{-1}; 2,155.1 kg ha^{-1} to 3,445.2 kg ha^{-1}, and 3,562.4 kg ha^{-1} to 4,309.6 kg ha^{-1}, respectively. In this current experiment, the net production of tilapia over a period of 120 days was 947.5 (± 100.9) kg ha^{-1}, 3592.5 (± 174.6) kg ha^{-1}, and 3332.5 (± 259.5) $kgha^{-1}$ in T_1, T_2, and T_3, respectively. The best feed efficiency or lowest feed conversion ratio was for tilapia raised on fertilizer and supplementary feed at 50% ration level. The net production performances of silver carp were 620 (± 132.2) kg ha^{-1}, 635 (± 110.9) $kgha^{-1}$, and 512.5 (± 88.35) $kgha^{-1}$ in T_1, T_2, and T_3, respectively. The highest net production of silver carp was obtained in T_2 and the lowest in T_3. Paul (1998) and Nahid (2006) obtained Silver carp production of 390.1 kg ha^{-1} to 471.3 kg ha^{-1} and 457.30 to 794.32 kg ha^{-1}, which was comparable to the present study.

The total production of tilapia and Silver carp was highest with fish raised on combined fertilizer and supplementary feed at the 50% ration level relative to those raised on fertilizers or 100% feed ration alone, which is similar to previous results seen with tilapia grown in monoculture (Diana et al. 1994). The T_2 group also had the best feed efficiency and the highest benefit-cost ratio, suggesting the polyculture of tilapia and Silver carp on combined fertilizer and 50% ration inputs is more economical than that of fishes raised either on fertilizer or feeds alone. Collectively, these results suggest that farmers can grow tilapia with silver carp to diversify their crops with no loss in biomass harvested and improve their incomes with combined fertilization and supplemental feeding of commercial diets. Further studies are needed to establish if higher stocking densities or even lower feed rations might provide additional cost savings to farmers who adopt carp and tilapia polyculture in Bangladesh.

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Table 1. *Characterizations of prawn pond farming systems in Southwest Bangladesh.*

Pond ID	**Shape, Size & Water Depth**	**Water Source & availability**	**Stocking Density & PL Size**	**Pre-stocking Management**	**Post-stocking Management**	**Feed Type**	**Farming Period**
01	Rectangular, 0.4ha, 1.5m	Rainfall & ground water, 12 months	25,000ha^{-1}, 5mm	Tilling: By Tractor Liming: 250 $kgha^{-1}$ Fertilizer: N/A	G.C: 15 days Interval F.T.C: Daily	Mega Starter, grower, farmed made	June-April/May
02	Rectangular, 1.0 ha, 1.5m	Rainfall & ground water, 12 months	20,000ha^{-1}, 5mm	Tilling: By Tractor Liming: 250 $kgha^{-1}$ Fertilizer: N/A	G.C: 15 days Interval F.T.C: Daily	Mega Starter, grower, farmed made	June-April/May
03	Rectangular, 0.8 ha, 2 m	Rainfall & ground water, 12 months	22,500ha^{-1}, 5mm	Tilling: By Tractor Liming: 250$kgha^{-1}$ Fertilizer: N/A	G.C: 15 days Interval F.T.C: Daily	CP Feed, Mus. Oil cake, farmed made	June-April/May
04	Rectangular, 0.6 ha, 2 m	Rainfall & ground water, 12 months	17,500ha^{-1}, 5mm	Tilling: By Tractor Liming: 250 $kgha^{-1}$ Fertilizer: N/A	G.C: 15 days Interval F.T.C: Daily	CP Feed, Mus. Oil cake, farmed made	June-April/May

*G.C: Growth Checking, *F.T.C: Feeding Tray Checking

Table 2. *Characterizations of prawn gher culture systems in Southwest Bangladesh.*

Gher ID	Shape, Size & Water Depth	Water Source & availability	Stocking Density & PL Size	Pre-stocking Management	Post-stocking Management	Feed Type	Farming Period
05	Rectangular, 6.8 ha, 1.5m	Rainfall, ground water & canal, 6 months	30,000ha^{-1}, 7mm	Tilling: By Tractor Liming: 150kgha^{-1} Fertilizer (kgha^{-1}): Urea-25, TSP-15	G.C: 7 days Interval F.T.C: Daily	Mega Starter, grower, Quality, farmed made	June/July - Dec/Jan
06	Rectangular, 0.8 ha, 1.5m	Rainfall, ground water & canal, 6 months	22,500ha^{-1}, 8mm	Tilling: By Tractor Liming: 250 kgha^{-1} Fertilizer (kgha^{-1}): Urea-15, TSP-10	G.C: 7 days Interval F.T.C: Daily	Mega Starter, grower, farmed made	June/July - Dec/Jan
07	Rectangular, 0.4 ha, 2 m	Rainfall, ground water & canal, 6 months	25,000ha^{-1}, 8mm	Tilling: By Tractor Liming: 150 kgha^{-1} Fertilizer (kgha^{-1}): Urea-15, TSP-8	G.C: 7 days Interval F.T.C: Daily	Mega Starter, grower, Quality, farmed made	June/July - Dec/Jan
08	Rectangular, 0.6 ha, 1.5m	Rainfall, ground water & canal, 6 months	25,000ha^{-1}, 8mm	Tilling: By Tractor Liming: 150kgha^{-1} Fertilizer (kgha^{-1}): Urea-15, TSP-8	G.C: 7 days Interval F.T.C: Daily	Mega Starter, grower, farmed made	June/July - Dec/Jan

*G.C: Growth Checking, *F.T.C: Feeding Tray Checking

Table 3. *Factorial analysis results of environmental parameters and the prawn pond and prawn gher culture system in Southwest Bangladesh.*

Factor:	**Factor1**	**Factor2**	**Factor3**
Water depth	-0.89	-0.03	0.02
Salinity	0.81	-0.19	-0.00
Alkalinity	0.72	0.35	0.20
Secchi	-0.81	0.19	0.23
Chlorophyll	-0.12	-0.05	0.75
pH	0.29	0.44	0.56
DO	0.23	-0.65	0.45
Ammonium	0.34	0.71	-0.10
Nitrite	0.66	-0.29	-0.13
Explained variance (%)	37%	16%	13%
Factor Interpretation	rain effects, liming effect, and delay of 2nd nitrification step	decomposition vs. photosynthesis	photosynthesis
ANOVA			
Significance	***	***	*
r^2	0.90	0.61	0.23
Sources of variance	**Sig., %SS**	**Sig., %SS**	**Sig., %SS**
treatment	*, 1	*, 5	**, 50
date	***, 99	***, 95	NS, 50
Mean multicomparisons by treatment			
Pond, only prawn culture	b	a	a
Gher, prawn culture with previous rice culture	a	b	b
Mean multicomparisons by date			
2-Jul (before PL stocking)	a	c	a
17-Jul	b	b	a
5-Aug	c	a	a
23-Aug	c	a	a
9-Sep	de	b	a
27-Sep	e	bc	a
8-Oct	d	b	a
30-Oct	de	b	a

Underlined factor coefficients were used for interpretation. r^2 = coefficient of determination). Sig = significance. Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001, NS = not significant. %SS = percentage of total sums of squares. Mean multicomparisons: same letters in each column indicate no significant differences at the 0.05 level. n=64 observations**.**

Table 4. *Analyses of sediment parameters in prawn pond and gher culture systems in Southwest Bangladesh.*

Date	ID	pH	Organic Carbon (%)	Total-N (%)	P (ppm)	Sand (%)	Silt (%)	Clay (%)	Texture type
2/7/12 **(In Pond System)**									
	1	6.48	1.805	0.158	21.26	11	72	17	Silt loam
	2	7.1	1.628	0.142	19.05	7	62	27	silt clay loam
	3	7.2	1.605	0.14	7.62	11	62	27	silt clay loam
	4	7.28	1.166	0.102	12.33	13	80	7	Silt loam
30/10/12									
	1	6.96	1.896	0.168	13.23	6	56	38	silt clay loam
	2	7.26	1.024	0.178	15.64	6	66	28	silt clay loam
	3	7.47	1.787	0.159	18.85	6	56	38	silt clay loam
	4	7.36	1.886	0.17	18.35	6	74	20	Silt loam
Mean ± SD		7.1 ± 0.3	1.60 ± 0.33	0.15 ± 0.02	15.8 ± 4.8	8.3 ± 2.9	66 ± 8.7	25.3± 10.5	
2/7/12 **(In Gher System)**									
	5	6.65	4.448	0.386	17.55	17	16	67	clay
	6	6.88	2.206	0.193	16.95	11	66	23	Silt loam
	7	6.9	1.987	0.174	12.13	13	42	45	silt clay
	8	6.76	1.277	0.114	8.12	29	44	27	clay loam
30/10/12									
	5	6.7	4.485	0.387	14.04	20	42	38	clay loam
	6	7.06	1.932	0.346	9.72	18	64	18	Silt loam
	7	5.56	1.805	0.156	7.22	12	56	32	silt clay loam
	8	5.38	1.805	0.158	9.82	14	66	20	silt clay loam
Mean ± SD		6.5 ± 0.64	2.49 ± 1.24	0.23 ± 0.11	11.9 ± 3.9	16.7 ±5.8	50± 17.1	33.7± 16.2	

Table 5. *Production of freshwater prawn in pond and gher culture systems.*

Treatment	Pond ID	Pond Area (ha)	Total Production (kg)	Total Production (kg ha^{-1})	Mean Production (kg ha^{-1}) (±SD)
Pond System	1	0.4	170	425	407.5 ± 15.55
	2	1	390	390	
	3	0.8	320	400	
	4	0.6	250	415	
Gher System	5	6.8	2400	350	335 ± 19.15
	6	0.8	250	310	
	7	0.4	140	350	
	8	0.6	200	330	

Table 6. *Mean monthly water quality and production variables for 0.10-ha. earthen ponds stocked with freshwater prawns (Marcobrachium rosenbergii) and fertilized weekly with either a pelleted organic fertilizer or the same fertilizer in powder form. Ponds were harvested after 104 days.*

	Pelleted Treatment								Powder Treatment							
	Pond 14				Pond 15				Pond 11				Pond 18			
Variable	June	July	August	September	June	July	August	September	June	July	August	September	June	July	August	September
Dissolved Oxygen (mg/L)	9.01 ± 1.06	13.23 ± 0.40	10.54 ± 1.09	8.31 ± 2.13	9.24 ± 0.65	5.75 ± 0.90	10.48 ± 1.44	12.89 ± 2.08	2.11 ± 0.39	7.93 ± 2.09	7.20 ± 0.41	8.34 ± 0.91	7.92 ± 1.78	6.78 ± 0.24	7.63 ± 1.50	9.26 ± 1.65
Temperature (°C)	26.8 ± 3.3	30.7 ± 0.7	29.5 ± 0.5	27.7 ± 2.6	27.9 ± 1.2	29.5 ± 0.8	29.6 ± 0.6	27.2 ± 3.1	27.3 ± 1.1	29.6 ± 0.3	28.3 ± 0.4	26.1 ± 2.6	28.1 ± 1.7	30.5 ± 1.0	29.2 ± 0.7	27.5 ± 2.4
pH	8.3 ± 0.1	9.1 ± 0.4	9.4 ± 0.2	7.9 ± 0.2	8.4 ± 0.2	8.2 ± 0.3	8.7 ± 0.1	8.9 ± 0.1	7.9 ± 0.2	7.3 ± 0.4	8.2 ± 0.1	8.1 ± 0.2	8.4 ± 0.2	8.0 ± 0.2	8.3 ± 0.1	8.2 ± 0.0
Alkalinity (mg/L)	380	243 ± 11	216 ± 2	238 ± 0	380	291 ± 5	279 ± 2	259 ± 5	434	323 ± 4	311 ± 4	291 ± 0	366	287 ± 1	280 ± 6	271 ± 0
Ammonia (mg/L NH_3-N)	0.55 ± 0.03	0.34 ± 0.02	0.35 ± 0.02	0.50 ± 0.01	0.81 ± 0.06	0.71 ± 0.12	0.68 ± 0.04	0.44 ± 0.05	0.71 ± 11	0.68 ± 0.09	0.81 ± 0.10	0.62 ± 0.14	0.76 ± 0.05	0.71 ± 0.17	0.71 ± 0.07	0.39 ± 0.03
Nitrite (mg/L NO_2^-)	0.52 ± 0.10	0.31 ± 0.18	0.62 ± 0.00	0.16 ± 0.16	0.31 ± 0.18	0.72 ± 0.10	0.31 ± 0.17	0.62 ± 0.31	0.47 ± 0.13	1.24 ± 0.31	1.12 ± 0.29	0.62 ± 0.00	0.21 ± 0.21	0.62 ± 0.18	0.74 ± 0.16	1.09 ± 0.47
Nitrate (mg/L NO_3-N)	0.2	0.4 ± 0.1	0.5 ± 0.0	0.4 ± 0.3	0.2	0.2 ± 0.2	0.6 ± 0.1	0.3 ± 0.0	0.6	0.5 ± 0.2	0.2 ± 0.1	0.1 ± 0.1	0.0	0.8 ± 0.1	0.5 ± 0.2	0.6 ± 0.4
Phosphorus (mg/L PO_4^{3-})	0.12	0.57 ± 0.16	1.97 ± 0.54	2.81 ± 0.46	0.75	1.86 ± 0.09	3.19 ± 0.49	3.59 ± 0.12	0.21	1.46 ± 0.35	4.51 ± 0.47	3.50 ± 0.00	0.09	1.01 ± 0.17	2.28 ± 0.33	2.50 ± 0.19
Chlorophyll A (µg/L)	10.19 ± 5.62	4.76 ± 1.69	7.77 ± 3.13	25.13	31.76 ± 3.43	30.58 ± 4.99	84.80 ± 14.11	72.38	10.01 ± 0.88	51.15 ±10.48	46.01 ± 11.54	49.90	19.48 ± 7.00	29.54 ± 2.92	56.00 ± 16.19	56.03
Secchi Depth (inches)	25 ± 4	27 ± 3	30 ± 0	16 ± 3	16 ± 7	10 ± 0	13 ± 1	13 ± 1	23 ± 6	20 ± 2	16 ± 1	19 ± 1	12 ± 1	13 ± 2	14 ± 1	18 ± 1
Evaporation (inches)	0.123 ± 0.014	0.124 ± 0.009	0.136 ± 0.007	0.106 ± 0.004	0.123 ± 0.014	0.124 ± 0.009	0.136 ± 0.007	0.106 ± 0.004	0.123 ± 0.014	0.124 ± 0.009	0.136 ± 0.007	0.106 ± 0.004	0.123 ± 0.014	0.124 ± 0.009	0.136 ± 0.007	0.106 ± 0.004
Total Fed (kg)	-	67.86	114.25	88.45	-	67.86	114.25	88.45	-	67.86	114.25	88.45	-	67.86	114.25	88.45
Initial Stocking Weight (kg)	0.408				0.408				0.408				0.408			
Average Weight (g)	0.136				0.136				0.136				0.136			
Final Weight (kg)	-				48.74				-				38.06			
Average Weight (g)	-				28.69				-				31.30			
% Survival	-				57%				-				41%			

Table 7. *Summary of mean (± SEM) water quality and production variables according to treatment (Pelleted versus Powdered fertilizers) after a 104-day growout trial in ponds stocked with freshwater prawns (Macrobrachium rosenbergii).*

	Pelleted Treatment	**Powder Treatment**
Dissolved Oxygen (mg/L)	9.97 ± 0.57	7.06 ± 0.55
Temperature (°C)	28.8 ± 0.5	28.5 ± 0.4
pH	8.68 ± 0.12	8.08 ± 0.09
Alkalinity (mg/L)	265 ± 11	305 ± 9
Ammonia (mg/L NH_3-N)	0.55 ± 0.04	0.70 ± 0.04
Nitrite (mg/L NO_2)	0.45 ± 0.06	0.79 ± 0.10
Nitrate (mg/L NO_3-N)	0.4 ± 0.0	0.4 ± 0.1
Phosphorus (mg/L PO_4^{3-})	2.13 ± 0.28	2.44 ± 0.33
Chlorophyll-A (ug/L)	34.11 ± 7.52	41.68 ± 5.48
Secchi Depth (inches)	19 ± 2	16 ± 1
Evaporation (inches)	0.123 ± 0.004	0.123 ± 0.004
Total Feed (kg)	596.48	596.48
Initial Stocking Biomass (kg)	0.408	0.408
Average Initial Weight (g)	0.136	0.136
Final Harvest Biomass (kg)	48.74	38.06
Average Final Weight (g)	28.69	31.30
Survival	57%	41%

Table 8. *Summary (mean) of physical characteristics and water budget measurements of four, earthen ponds used for culture of freshwater prawns (Macrobrachium rosenbergii) in Eastern North Carolina.*

Variable	**Value**
Pond area (m^2)	1110.7
Pond volume (m^3)	42,559
Pond Depth in meters (max/min)	1.67 (1.73/1.61)
Evaporation (cm/day)	0.312
Seepage (cm/day)	0.322

Table 9. *Water quality parameters in tilapia-carp polyculture in ponds with fertilization alone, fertilization + 50% feed ration, or feed alone at 100% ration. Mean (± SEM) and range of values.*

Parameters	**Treatments**			**Significance Level & Coefficient of Determination**
	T_1	**T_2**	**T_3**	
Air Temperature (°C)	30.21±0.12 (28.0-32.0)	30.21±0.12 (28.0-32.0)	30.21±0.12 (28.0-32.0)	1.000 r^2=0.000
Water Temperature (°C)	31.34±0.14 (30.0-34.5)	31.32±0.13 (30-34.50)	31.45±0.13 (30-34.80)	0.700 r^2=0.002
Transparency (cm)	33.67±0.74^a (21.0-50.0)	42.67±0.16^b (19.0-65.0)	39.0±0.13^c (21.0-55.0)	0.000*** r^2=0.06
pH	8.95^a (6.99-10.86)	8.70^{ab} (6.79-10)	8.50^b (6.89-10.09)	.0140* r^2=0.05
DO (mg l^{-1})	5.35±0.12 (3.36-7.50)	5.32±0.19 (1.75-8.48)	5.22±0.15 (2.20-8.26)	0.828 r^2=0.002
Alkalinity (mg l^{-1})	94.35±2.75 (8.0-144.0)	95.57±2.28 (67.0-144.0)	91.95±2.34 (64-152)	0.573 r^2=0.003
Nitrate (mg l^{-1})	0.05±0.007^a (0.01-0.21)	0.07±0.007^{ab} (0.00-0.25)	0.09±0.01^b (0.01-0.51)	0.040* r^2=0.03
Nitrite (mg l^{-1})	0.03±0.004 (0.00-0.12)	0.04±0.007 (0.00-0.26)	0.04±0.006 (0.00-0.25)	0.608 r^2=0.001
Ammonia (mg l^{-1})	0.42±0.04^{ab} (0.15-1.27)	0.54±0.05^a (0.19-1.57)	0.34±0.02^b (0.14-1.26)	0.002** r^2=0.01
Phosphate (mg l^{-1})	0.86±0.09 (0.08-3.0)	1.20±0.12 (0.26-3.0)	1.14±0.10 (0.16-3.0)	0.062 r^2=0.02
TDS (mg l^{-1})	56.73±2.19^a (25.60-108)	66.5±2.1^b (37.1-100.5)	69.72±2.20^b (42.0-109.0)	0.000*** r^2=0.09
Conductivity (µS cm^{-1})	112.11±3.53^a (55.0-157.90)	134.32±3.73^b (69.9-187.8)	144.67±3.57^b (90.0-203.0)	0.000*** r^2=0.19
Chlorophyll-*a* (µg l^{-1})	63.4±6.39 (10.0-250.0)	72.11±6.95 (10-250)	74.31±5.68 (2.0-150.0)	0.440 r^2=0.008

Significance level: * = $p < 0.05$, **= $p < 0.01$, *** = $p < 0.001$,
r^2= Coefficient of Determination
Mean values with different superscript letters in each row indicate significant differences between groups, if the main effects of treatment are significant.

__Table 10.__ Comparison of production parameters of tilapia and Silver carp under different treatments (means ± SEM).

Characters	Treatment			Significance Level & Coefficient of Determination
	T_1	T_2	T_3	
Oreochromis niloticus				
Mean stocking weight (g)	2.95 ± 0.16	3.0 ± 0.18	3.08 ± 0.18	NS r^2=0.98
Mean harvesting weight (g)	88.08 ± 14.87^b	250.2 ± 10.03^a	246.75 ± 7.53^a	*** r^2=0.39
Mean weight gain (g)	85.13 ± 14.87^b	247.2 ± 10.03^a	243.67 ± 7.53^a	*** r^2=0.39
Specific Growth Rate (SGR)	2.83 ± 0.004^a	3.69 ± 0.006^b	3.66 ± 0.005^c	*** r^2=0.72
Feed Conversion Ratio (FCR)	-	0.86 ± 0.03^b	1.88 ± 0.04^a	*** r^2=0.98
Survival (%)	81.25 ±3.19	86.75 ± 3.95	88.5 ± 3.23	NS r^2=0.19
Gross Production (kg ha^{-1})	1007.5 ± 100.9^b	3652.5 ± 174.6^a	3392.5 ± 259.5^a	*** r^2=0.62
Net Production (kg ha^{-1})	947.5 ± 100.9^b	3592.5 ± 174.6^a	3332.5 ± 259.5^a	*** r^2=0.62
Hypophthalmichthys molitrix				
Mean stocking weight (g)	18.1 ± 1.17	18.2 ± 1.16	18.2 ± 1.18	NS r^2=0.75
Mean harvesting weight(g)	286.08 ± 19.59	254.25 ± 15.82	240.25 ± 10.34	NS r^2=0.03
Mean weight gain (g)	267.98 ± 19.59	236.05 ± 15.82	222.05 ± 10.34	NS r^2=0.03
Specific Growth Rate (SGR)	2.30 ± 0.01^a	2.2 ± 0.01^b	2.15 ± 0.01^c	*** r^2=0.88
Survival (%)	100.00 ± 00	97.00 ± 3.00	92.0 ± 5.66	NS r^2=0.21
Gross Production (kg ha^{-1})	665 ± 132.2	680 ± 110.9	557.5 ± 88.35	NS r^2=0.04
Net Production (kg ha^{-1})	620 ± 132.2	635 ± 110.9	512.5 ± 88.35	NS r^2=0.04
Combined FCR	-	0.72 ± 0.02^b	1.62 ± 0.03^a	*** r^2=0.97
Combined Net Production (kg ha^{-1})	**1567.5 ± 207.5^b**	**4227.5 ± 135.5^a**	**3845 ± 342.47^a**	*** r^2=0.56

Significance level: * = p ≤0.05, **= p ≤0.01, *** = p ≤0.001, and NS= Not Significant
r^2= Coefficient of Determination
Treatment names: T_1 stands for fertilization alone, T_2 for fertilization + 50% feed, T_3 for 100% feed alone.
Mean values followed by different superscript letters in each row indicate significant differences based on Tukey's test, if the main effects are significant (p < 0.05).

Table 11: *Comparisons of economics among different treatments (based on 1 ha farm area & 4 months culture period.*

Items	**Treatments**		
	T_1	**T_2**	**T_3**
Financial Inputs			
Lime	1000	1000	1000
Urea	3000	3000	-
TSP	4500	4500	-
Feed	-	25000	50000
Tilapia Seeds	20000	20000	20000
Silver carp seeds	6000	6000	6000
Labor & Land rental cost	17000	17000	17000
Total Cost	51500	76500	94000
Bank Interest (12% annually)	6180	9180	11280
Total Investments	57680	85650	105280
Financial Returns			
Tilapia	50290	180000	170600
Silver carp	31000	35500	27200
Total Returns	81290[b]	215500[a]	197800[a]
Net Benefits	23520[b]	129850[a]	92520[a]
Benefit-cost ratio (BCR)	**1.40[b]**	**2.48[a]**	**1.88[a]**

Currencies are given in Bangladeshi Taka, BDT (1 USD= 80 BDT)

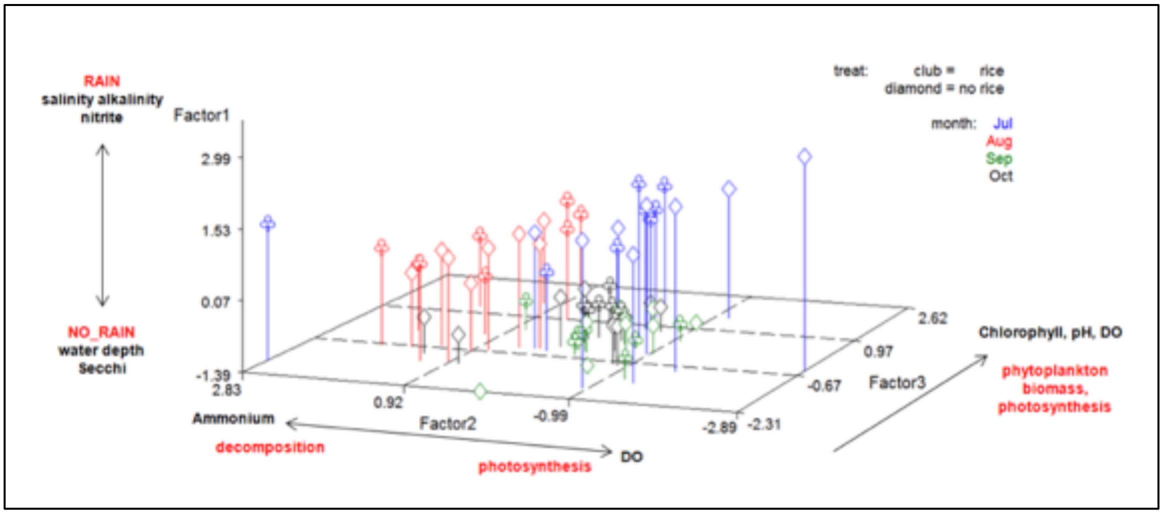


Figure 1. *Tridimensional plot of the 3 factors extracted for the prawn pond (no rice) and gher systems (rice).*

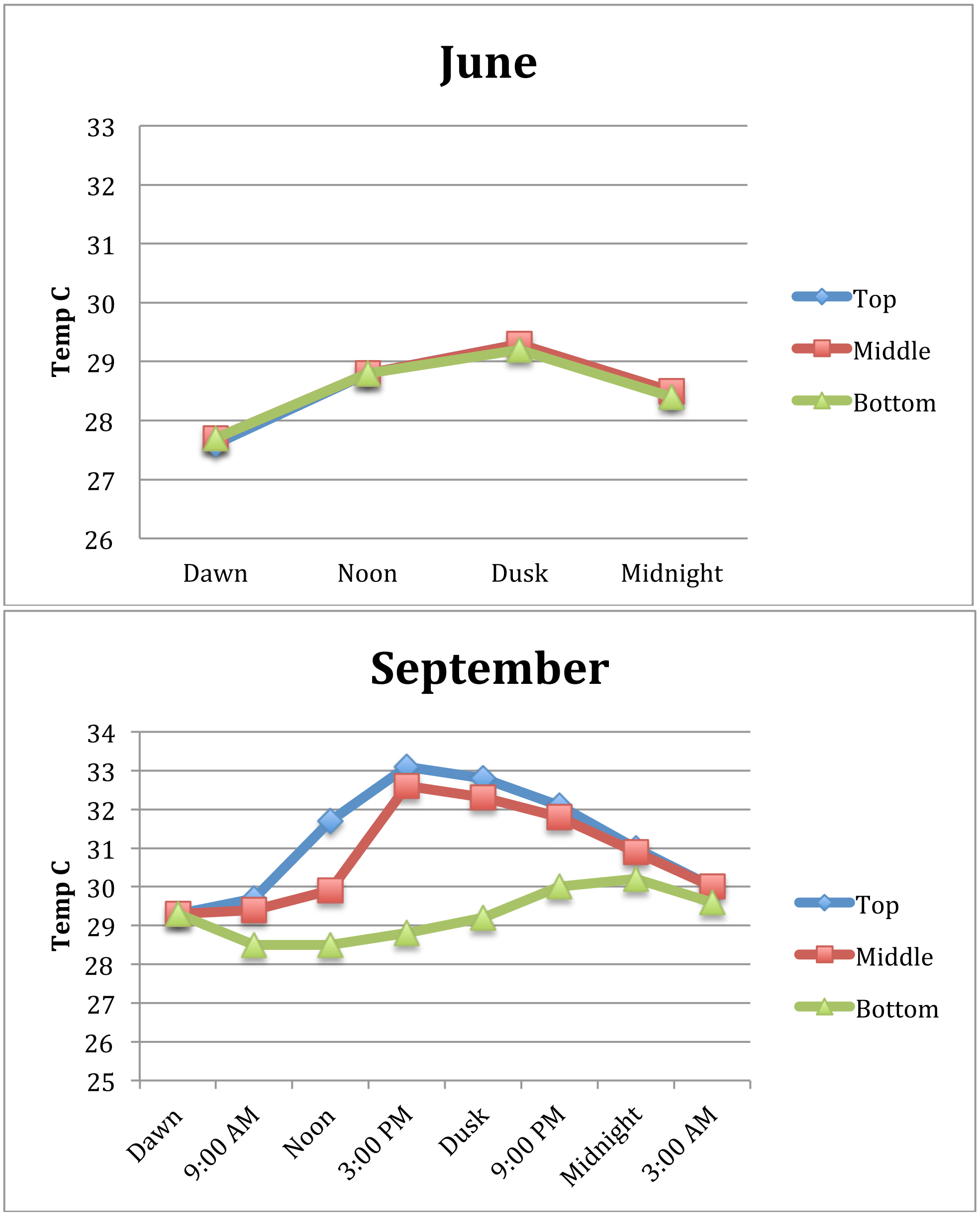


Figure 2. *Water temperature taken at different depths in a 0.10-ha earthen pond over a 24-h period during the month of June (top) and September (bottom) 2012.*

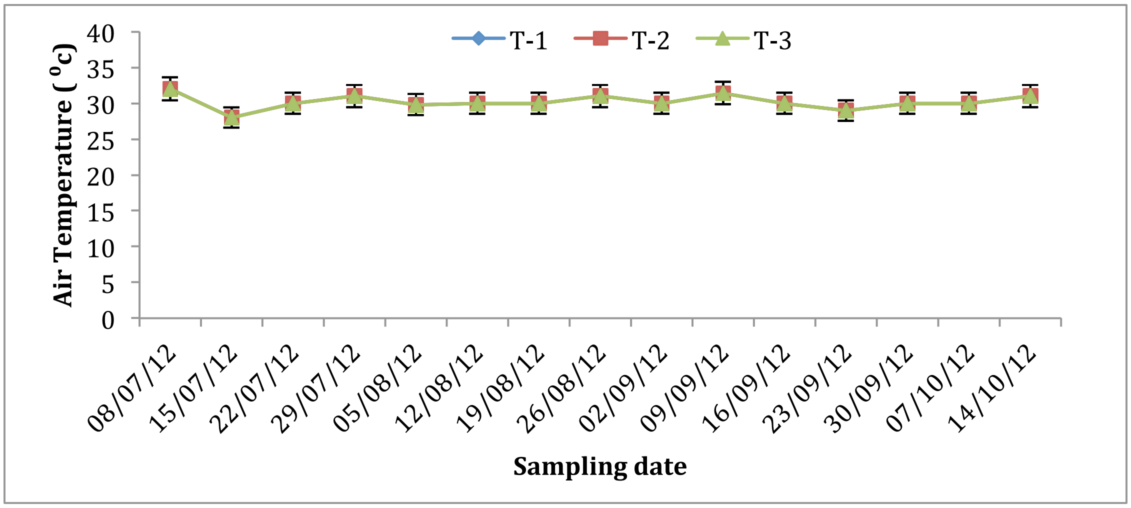


Figure 3. *Weekly variation of air temperature among three treatments.*

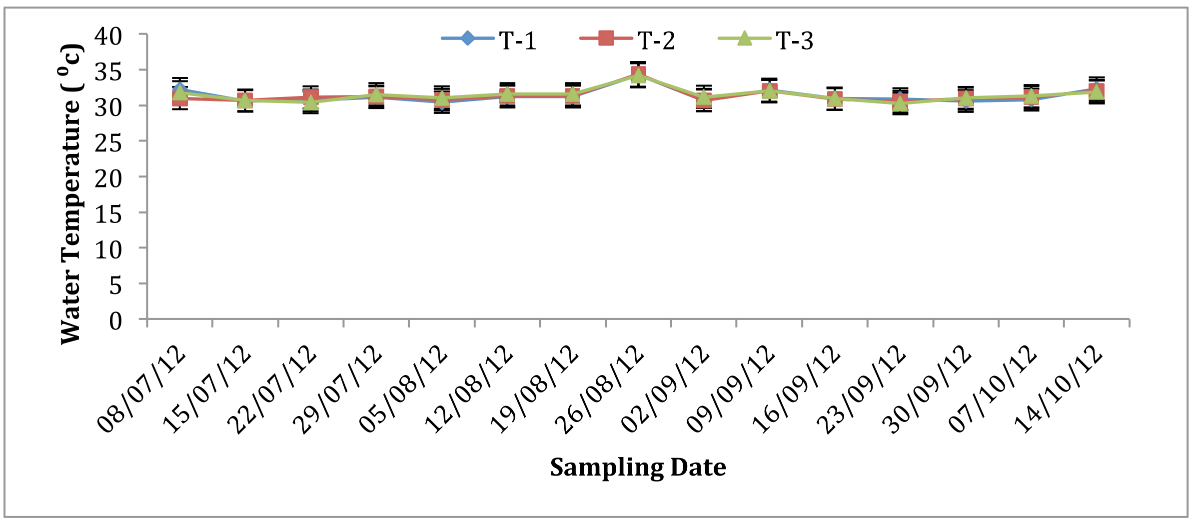


Figure 4. *Weekly variation of water temperature among three treatments.*

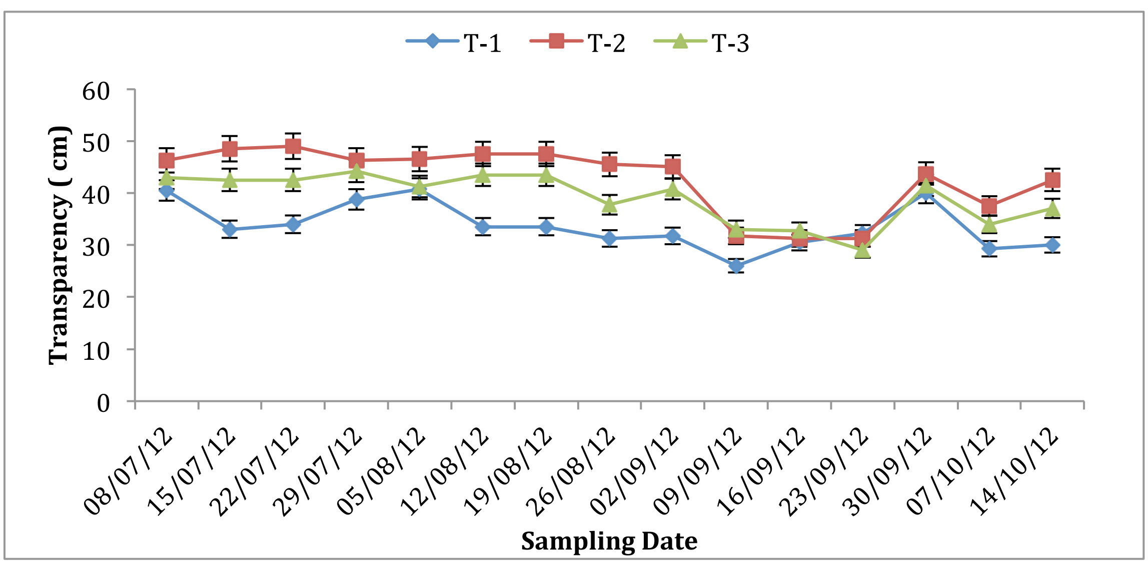


Figure 5. *Weekly variation of Transparency among three treatments.*

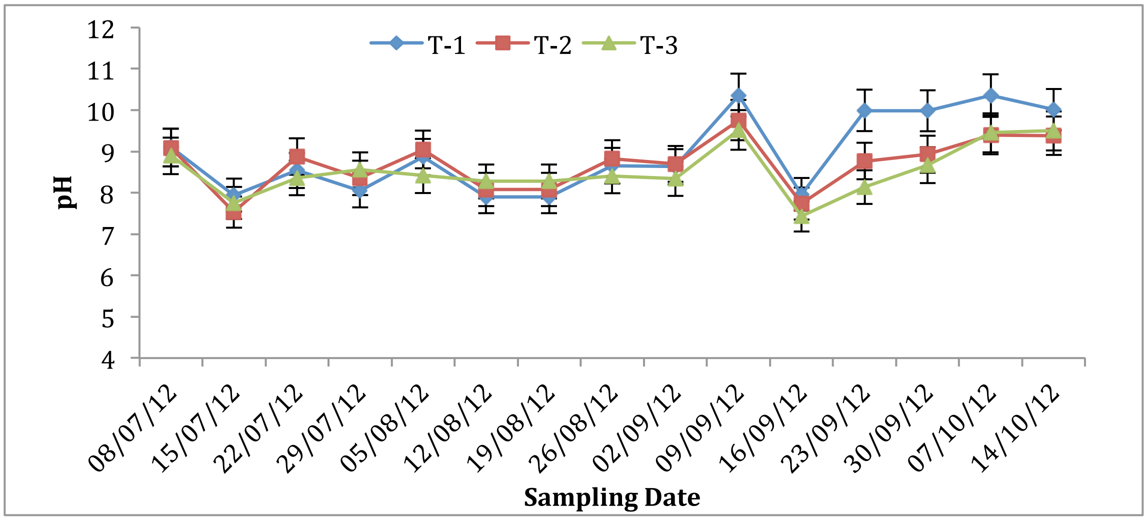


Figure 6. *Weekly variation of pH among three treatments.*

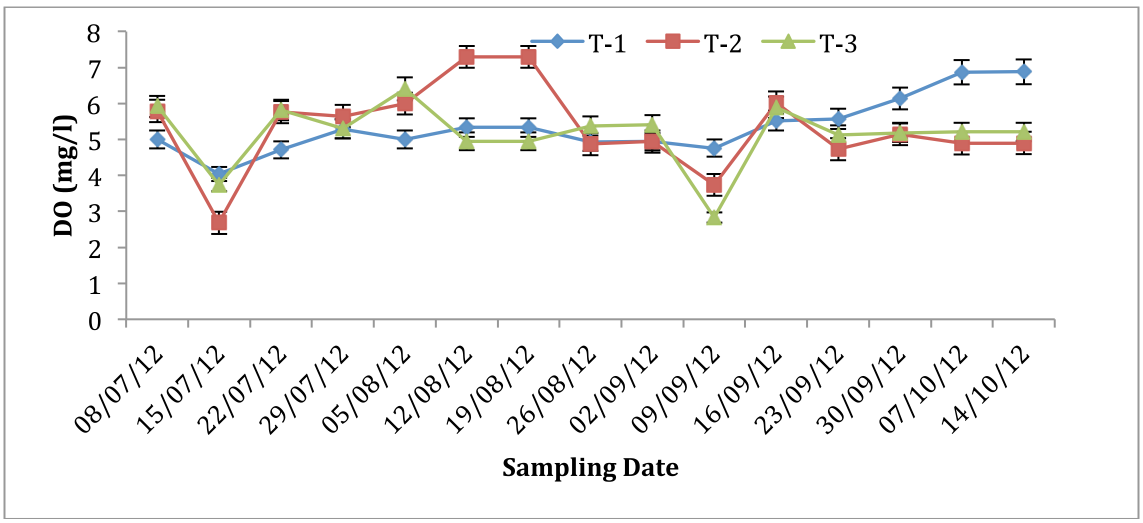


Figure 7. *Weekly variation of Dissolved oxygen among three treatments.*

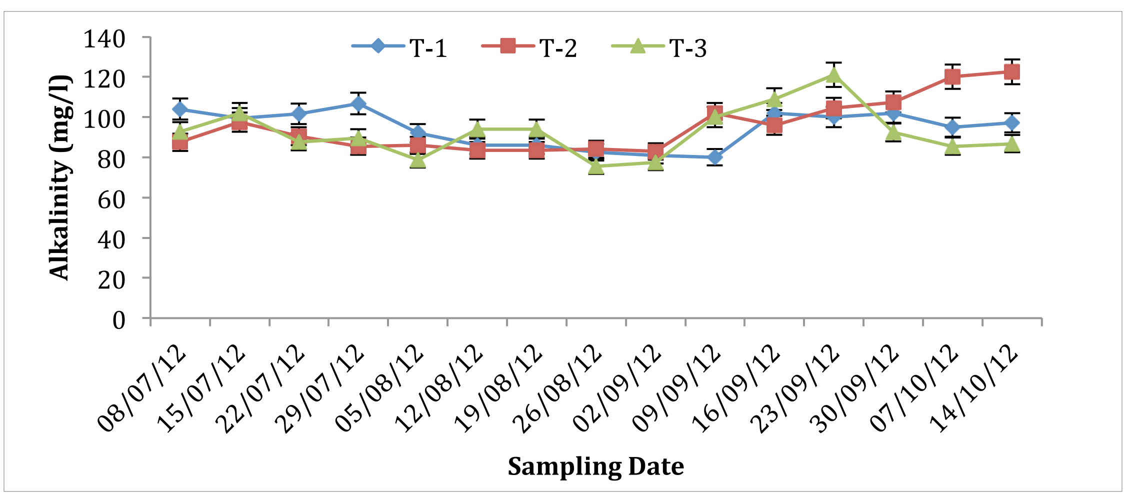


Figure 8. *Weekly variation of Total alkalinity among three treatments.*

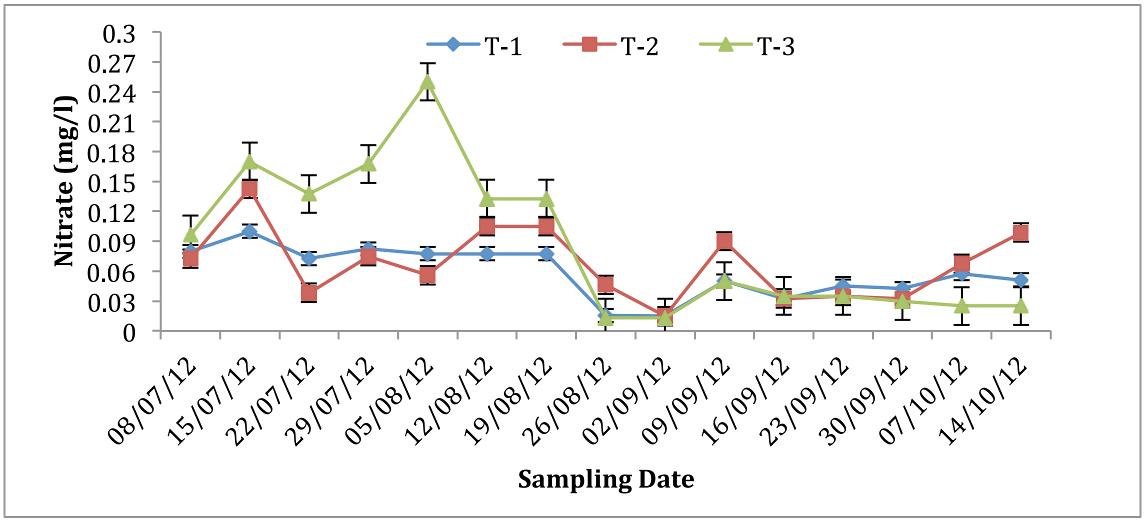


Figure 9. *Weekly variation of Nitrate-nitrogen among three treatments.*

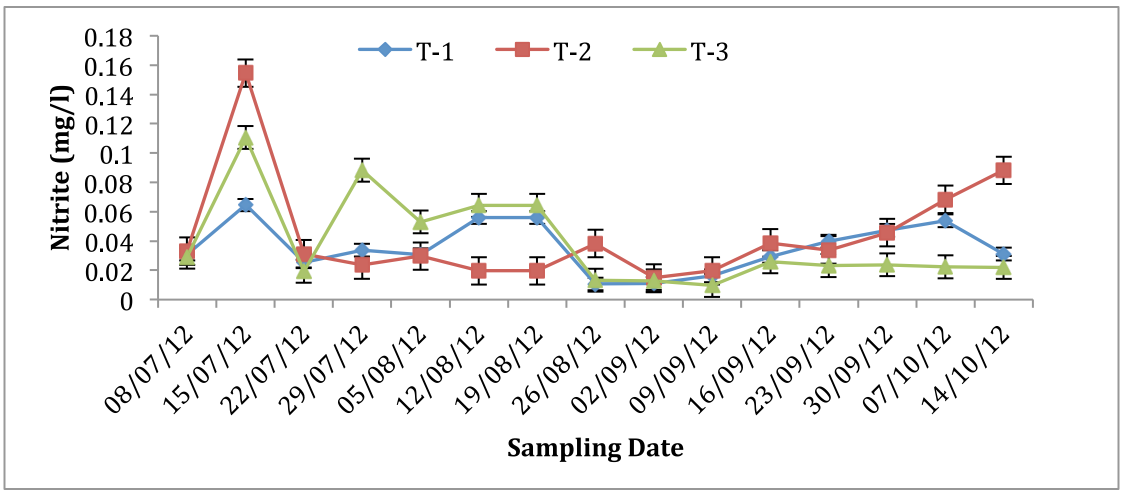


Figure 10. *Weekly variation of Nitrite-nitrogen among three treatments.*

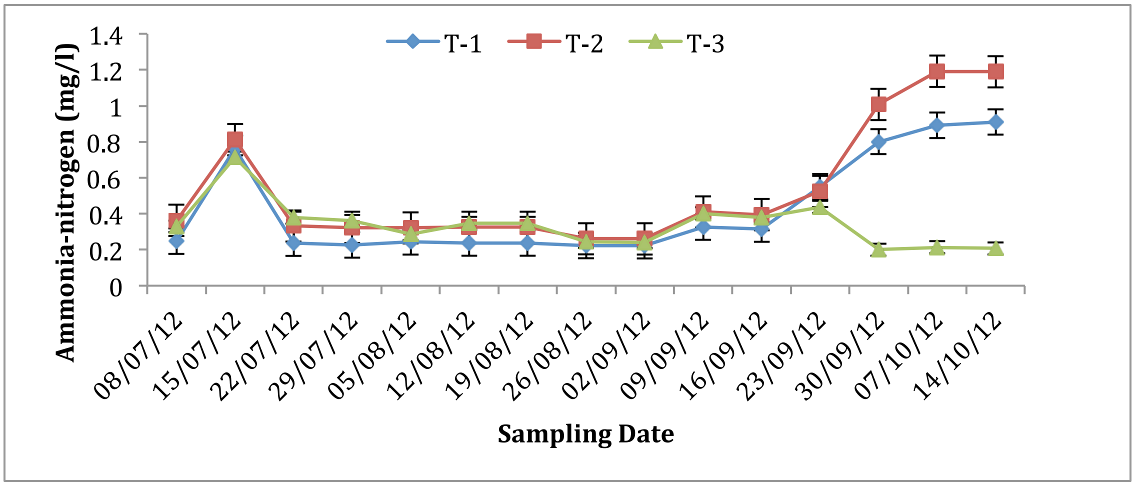


Figure 11. *Weekly variation of Ammonia-nitrogen among three treatments.*

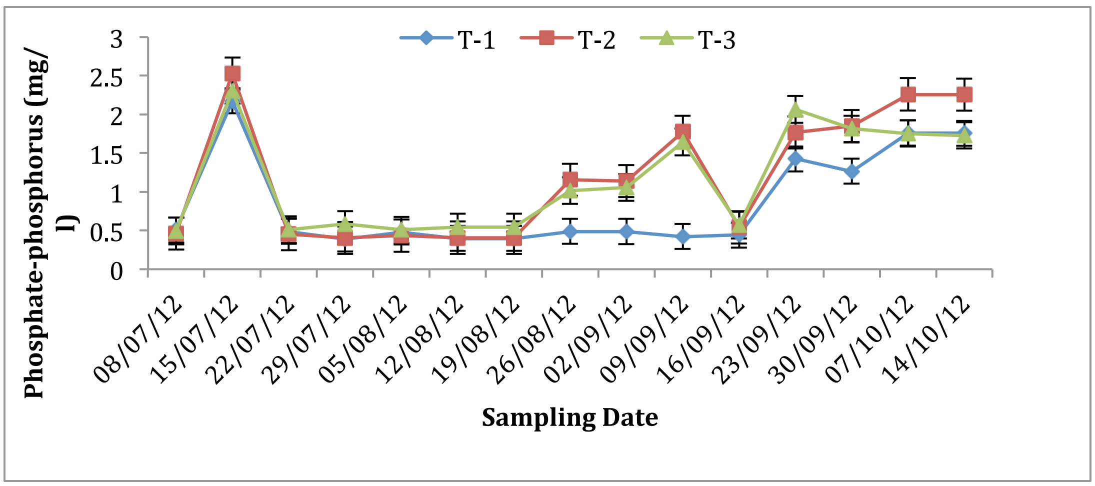


Figure 12. *Weekly variation of Phosphate-phosphorous among three treatments.*

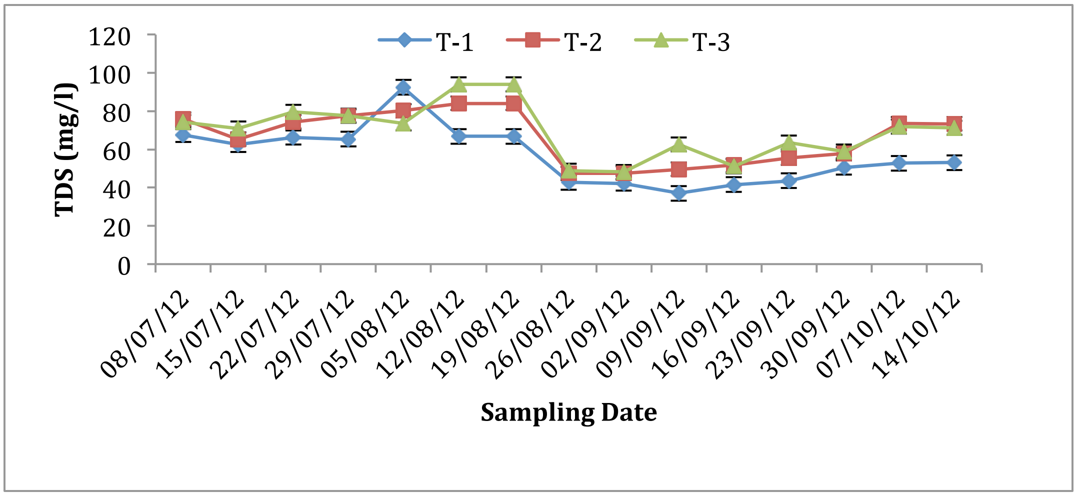


Figure 13. *Weekly variation of Total Dissolved Solid among three treatments.*

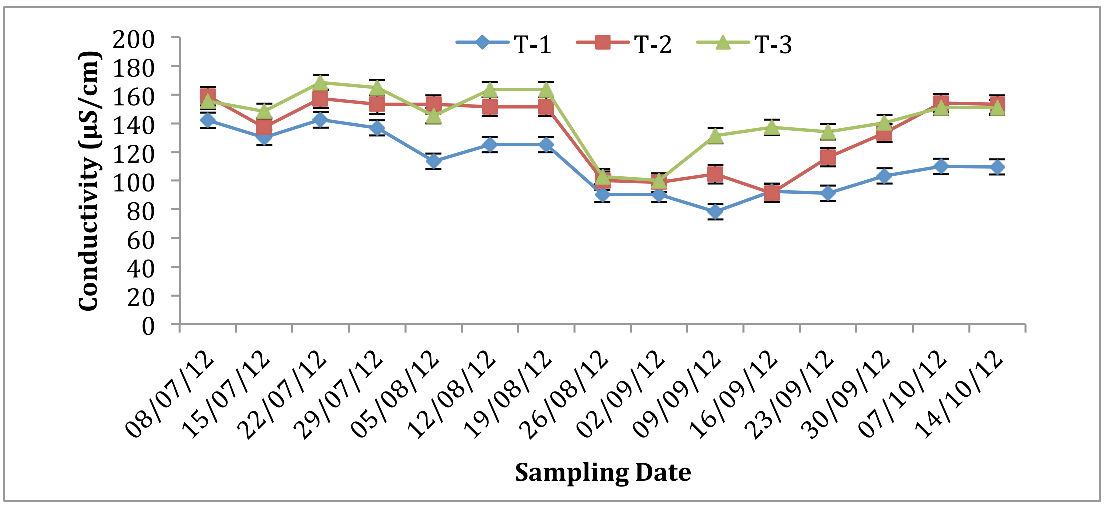


Figure 14. *Weekly variation of conductivity among three treatments.*

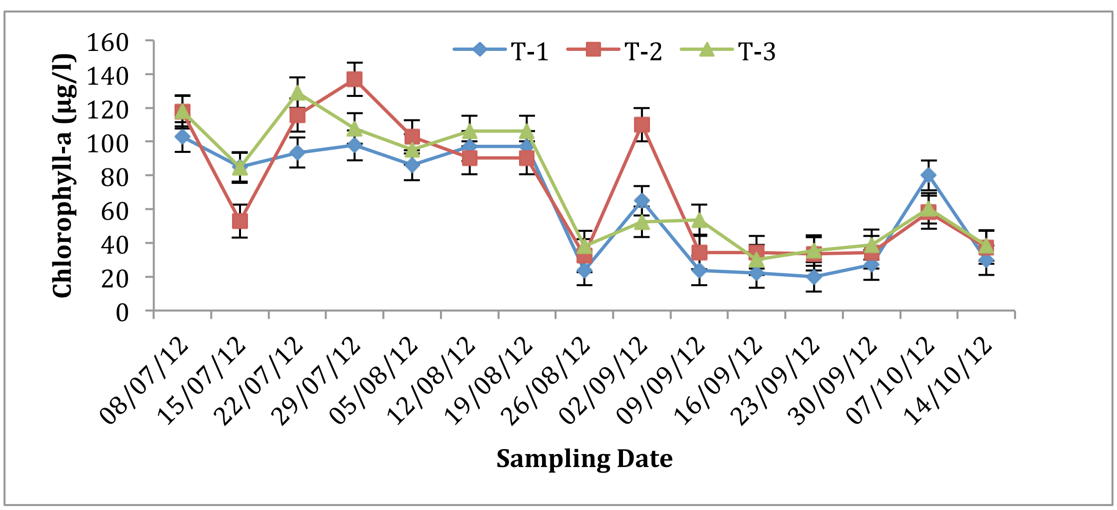


Figure 15. *Weekly variation of Chlorophyll-a among three treatments.*

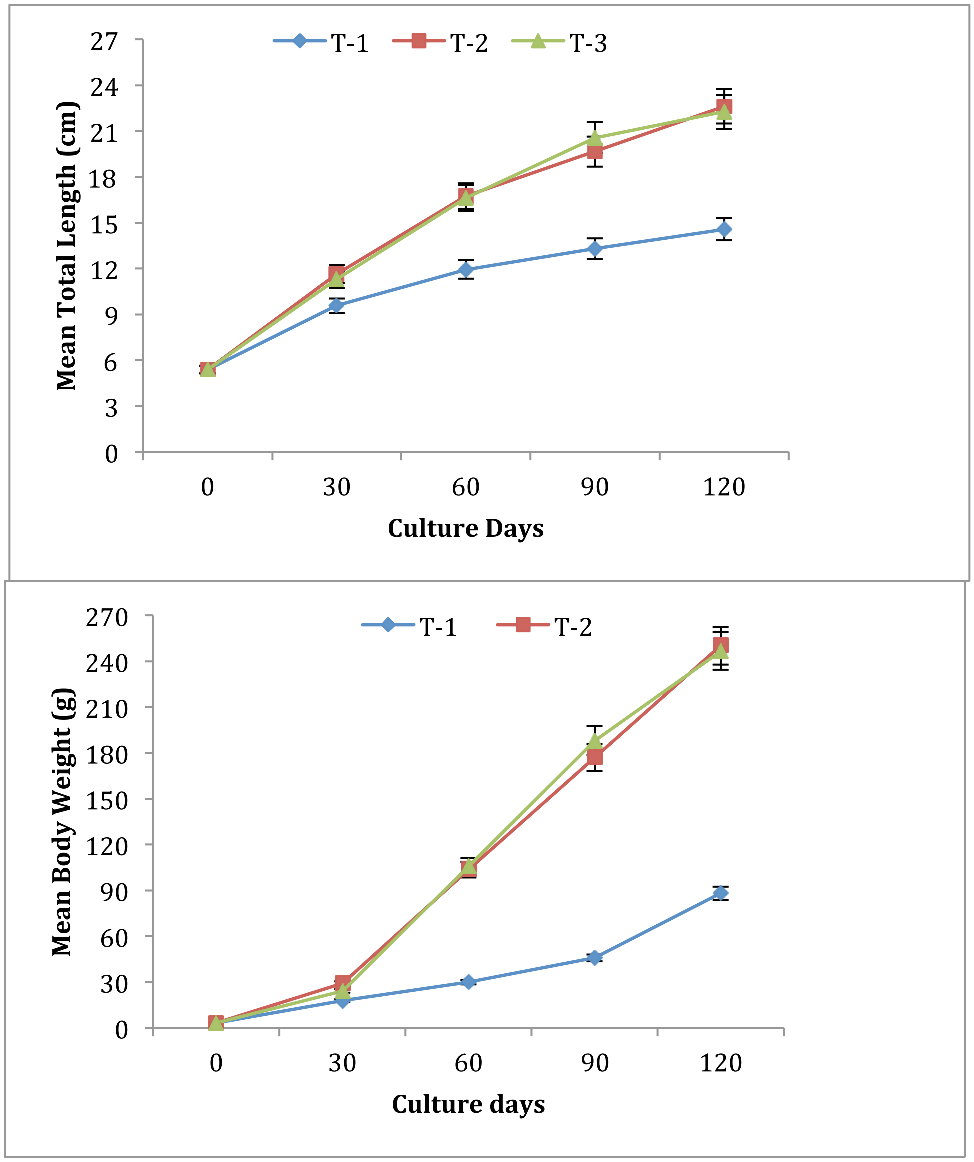
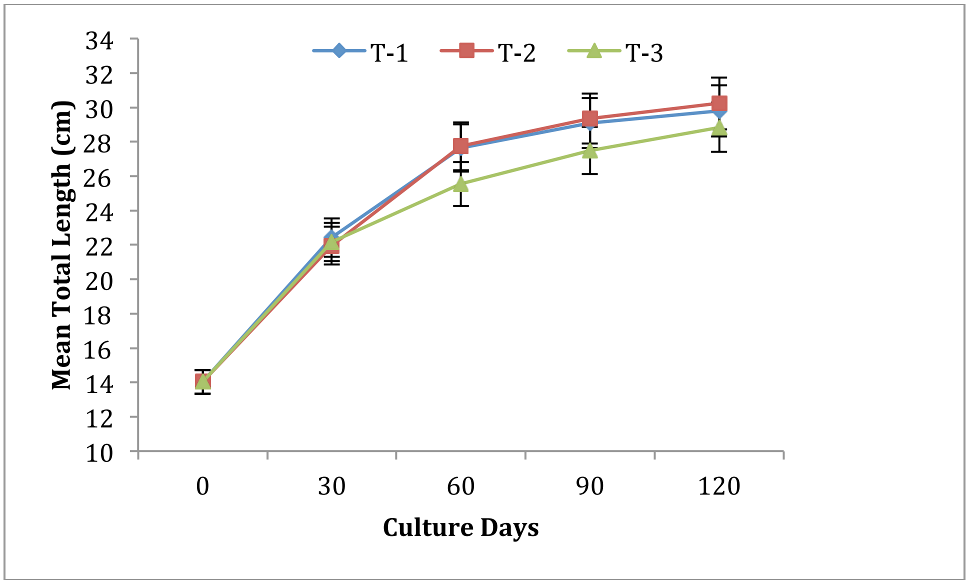


Figure 16. *Mean total length (cm) and mean body weight (g) of tilapia stocks.*



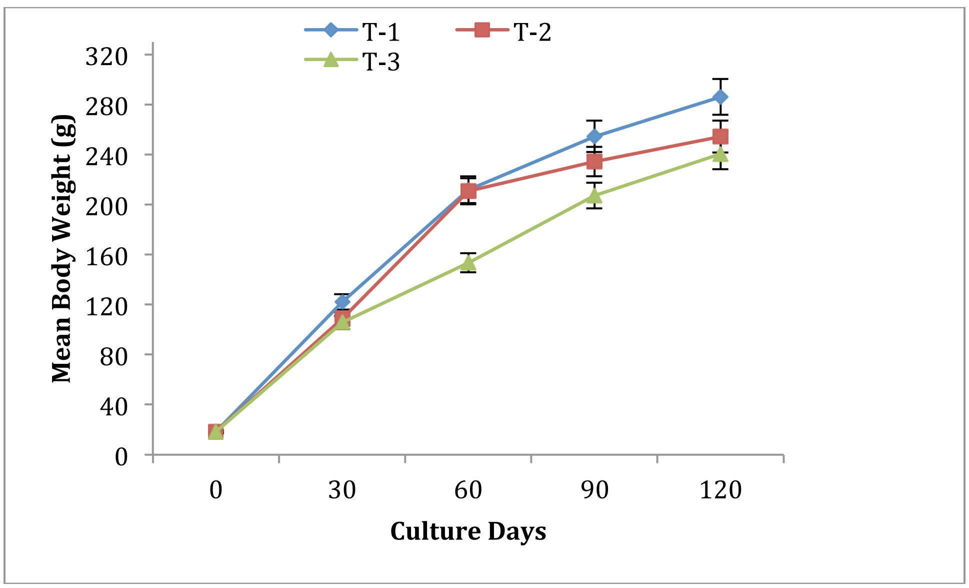


Figure 17. *Mean total length (cm) and body weight (g) of silver carp stocks.*

TOPIC AREA:
EXPERIMENTAL POND UNIT ASSESSMENT

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EXPERIMENTAL POND UNIT ASSESSMENT IN GHANA

Production System Design & Best Management Alternatives/Study/09BMA10PU

FINAL INVESTIGATION REPORT

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ABSTRACT

This report summarizes the experimental pond unit assessment of two facilities used in AquaFish research in Ghana. The facilities are KNUST farm and the Pilot Aquaculture Center (PAC) of the Fisheries Commission. The project took place from July to October 2012 and involved physical, chemical, and biological characterization of 10 ponds of which 8 were stocked with *Oreochromis niloticus* at 2 m^{-2} and 2 were not stocked. Overall, most of the variables originally planned for measurement were successfully completed and the project played a vital role in institutional and individual capacity building.

INTRODUCTION

In furtherance of the broader objectives of the AquaFish CRSP, a set of experimental sites are being developed across select countries in Africa, Asia, and the Americas, where common experiments will be carried out to investigate aquaculture technologies and management practices that may be transferable among regions. Better management practices developed through these activities will support sustainable development of aquaculture with minimum environmental impacts. The objectives of this study were to:

1. Evaluate ponds at two experimental sites for their physical, chemical, and biological characteristics during grow-out.
2. Develop a baseline set of physical, chemical, and biological characteristics of ponds for future AquaFish CRSP experiments.
3. Build on existing training opportunities, institutional networks, and research and extension capacity to promote small-scale aquaculture development in Ghana.

The overarching goal was to add value to the data obtained in related AquaFish studies, in addition to providing the needed baseline information for future experiments and validation of the capacity of AquaFish's collaborating institutions in Ghana to execute a rigorous protocol of water quality and environmental data collection.

METHODS AND MATERIALS

Location

The study was conducted in the Ashanti Region of Ghana. The primary site of the study was the Kwame Nkrumah University of Science and Technology (KNUST) farm situated on the campus of the university in Kumasi. The secondary site was the Pilot Aquaculture Center (PAC) of the Fisheries Commission, located at Tano-Odumasi, north of Kumasi. These sites were selected for their proximity to campus to facilitate transportation and timely sampling and water analyses during this intensive study. Both sites and 8 out of 10 of the selected ponds were also part of ongoing demonstration experiments of AquaFish, making the data ultimately useful for analyzing the results of the demonstrations.

Methods

The study was conducted for 3 months from July to October 2012 during half of the growout phase of the demonstration experiments. Four ponds at KNUST and four ponds at PAC were the primary focus. These ponds were already being used in AquaFish CRSP demonstration experiments involving comparison of tilapia (*Oreochromis niloticus*) growth on locally manufactured sinking feed (L), formulated floating feed (R), recycled pond water (OW), and fresh pond water (NW). Two additional ponds at the PAC site were included as controls (i.e., not stocked: CP1 & CP2) for a total of 10 ponds. We considered the two farms as replicates and ponds within a farm as subsamples to help estimate with-in site variation. The physical, chemical, and biological characterization of ponds was designed to follow the original scheme in Table 1.

Table 1: *Summary of variables originally intended for measurement and the frequency of measurements.*

Variable	Daily Frequency	How often	Type of sample
PHYSICAL & CHEMICAL			
Pond morphometry	-	Once	
Pond soils	-	Once	Composite
Pond depth	Once	Daily	One
Water depth	Once	Weekly	Whole pond
Evaporation	Once	3 times	One
Seepage	Once	3 times	One
Temperature	Diel measures	3 times	3 depths
DO	Diel measures	3 times	3 depths
DO	Once	Weekly at dawn	Composite
pH	Diel measures	3 times	3 depths
Alkalinity	Diel measures	3 times	3 depths
TP, TDS/Conductivity, TSS	Once	Weekly	Composite
TKN, NH_3/NH_4^+, NO_2/NO_3	Once	Weekly	Composite
BIOLOGICAL			
Secchi disk depth	Once	Weekly	Whole pond
Chlorophyll-a	Once	Weekly	Composite

Prior to the initiation of the study, a more detailed scheme of sampling was written, reviewed, and approved by the PIs. Necessary modifications of the set of variables that were deemed necessary and feasible under the local conditions were made at this time (Appendix 1). Field Technicians (4#)

followed the sampling scheme in Appendix 1 as closely as possible. The methods for pond physical characterization followed Egna et al. (1987), chapters in Egna and Boyd (1997), and the *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 2012) or an older version where specifically cited in Appendix 2. Field water quality measurements were made with a Hanna hand-held meter, except where indicated otherwise (e.g., Secchi depth). Lab analyses were conducted at the Department of Civil and Environmental Engineering of KNUST, and soil analyses were conducted at the Soil Research Institute of Ghana, Analytical Service Division in Kumasi.

Physical and chemical characterization-

The characteristics we measured include pond morphometry, pond soils, pond depth, evaporation rate, water temperature, and a suite of water chemistry variables. Morphometry was measured by measuring depths at 1-m intervals along two transects perpendicular across the pond, from the top of one bank to the opposite bank. These points were interpolated to develop a bathymetric map of each pond so that the surface area and pond volume can be calculated at each depth for the working pond. Pond depths were also measured at the deepest point daily, and served as the basis for weekly water replacements if needed. We measured evaporation rate with an evaporation pan. Amount of water discharged during rain, if any, and seepage were determined from the daily measurements of pond depth and evaporation.

Pond bottom soils were measured for their physical and chemical properties, with a suite of variables being partly determined by the capacity of the Soils Research Institute to which this work was contracted. Soil samples to be analyzed were collected at various locations from the pond bottom (before flooding for ponds that were dry prior to the sampling). Composite cores were taken from wet ponds. Water temperature, DO, pH, and Alkalinity were measured frequently (see protocol – Appendix 1, and results) and profiled vertically for each pond for surface, mid- depth, and bottom. The water chemistry variables that were measured in the laboratory include, phosphorus (as TP), various forms of nitrogen (TKN, NO_2, NO_3, and NH_3/NH_4^+), pH, alkalinity, and dissolved and suspended solids (TDS and TSS).

Biological characterization-

We estimated plankton standing crop by measuring light penetration, using the Secchi disc method. The compensation point is determined as 2 × Secchi disc depth. We also measured the concentration of chlorophyll-a for a more direct indication of phytoplankton biomass and pond productivity. Due to delays in obtaining equipment replacement parts, chlorophyll-a measurements lagged about a month behind the commencement of the study. Since the values of DO, pH, and temperature were being collected at 3 depths and on a regular basis over the diel period, we anticipate the use of these measurements to calculate the net primary productivity, respiration, and gross primary productivity of each pond. Each pond included one additional dawn, midday, dusk, midnight, and the following dawn's measurement of DO, pH, alkalinity, and temperature before the end of the experiment to allow for the use of templates developed by previous CRSP work to produce reliable estimates.

RESULTS & DISCUSSION

Raw results of all measurements taken are summarized here in a series of tables starting from Table 2 (and figures in the case of pond bottom contours). The detailed analysis, computations, and interpretations are done in conjunction with the reports on the demonstration studies. Additional tables that are too large are attached in excel files.

Training, capacity building, and networking-

In addition to the intensive data collection on pond dynamics, we utilized this research for training of students, fisheries officers, and farmers. This was accomplished by leveraging ongoing AquaFish CRSP work. We engaged 3 fisheries officers, 2 MPhil students, and 2 national service personnel of KNUST as field and laboratory technicians and as resource persons during scheduled workshops on pond water quality management and aquaculture BMPs. The following are some specific benefits of the EPUA to Ghana:

- Two research and development facilities, the KNUST fish farm and the PAC, were enhanced for their capacity to generate high-quality scientific information on pond and environmental soil and water quality, thereby providing the needed confidence in these facilities for use in future AquaFish CRSP research.
- KNUST and PAC personnel acquired further knowledge and practical skills, and will in turn train students and fisheries officers in various aspects of pond water quality management.
- Outreach opportunities continue to be provided through the Best Management Practices (BMP) workshops, where fisheries officers and farmers interact in a rare forum for extension, utilizing experience gained from this project.
- KNUST and the Fisheries Commission working together with Virginia Tech on this project furthers the objective of capacity building and institutional networking both within Ghana and across continents to benefit development of aquaculture in Ghana.

Table 2: *Results of soil analysis.*

DATE:	7/12/2012							
	pH 1:1				EXCHANGEABLE CATION me/100g			
POND ID	H2O	% ORG. C	% TOTAL N.	% ORG. M	Ca	Mg	K	Na
PAC-OWL	5.86	0.93	0.09	1.60	5.60	0.53	0.36	0.07
PAC - OWR	5.66	0.63	0.05	1.09	3.47	1.07	0.20	0.06
PAC NWR	5.68	0.81	0.07	1.40	3.74	2.40	0.34	0.12
PAC - NWL	6.05	0.66	0.06	1.14	3.74	2.4	0.14	0.05
FRNR-NWL	7.11	0.72	0.07	1.24	2.94	0.53	0.19	0.05
FRNR-OWL	7.04	0.30	0.03	0.52	4.27	0.53	0.21	0.06
FRNR-OWR	5.49	0.45	0.04	0.78	4.00	0.53	0.09	0.03
FRNR-NWR	6.35	0.72	0.07	1.24	2.94	2.14	0.08	0.01

	T.E.B	Exch. A (Al + H)	E.C.E.C Me/100g	% Base Sat	AVAILABLE-BRAY'S PPmP	PPmK	MECHANICAL ANALYSIS SAND	SILT	CLAY
PAC-OWL	7.19	0.50	7.69	93.50	14.00	34.15	41.86	50.14	8.00
PAC - OWR	4.80	0.60	5.40	88.90	21.00	67.97	51.72	40.28	8.00
PAC NWR	6.60	0.60	7.20	91.70	28.00	37.87	55.88	38.12	6.00
PAC - NWL	6.33	0.10	6.43	98.40	35.00	71.01	97.62	0.38	2.00
FRNR-NWL	3.71	0.08	3.79	97.90	21.00	24.69	83.74	14.22	2.04
FRNR-OWL	5.07	0.10	5.17	98.10	7.00	73.72	74.68	23.30	2.02
FRNR-OWR	4.65	0.80	5.45	85.30	28.00	16.57	74.88	23.67	2.05
FRNR-NWR	5.17	0.10	5.27	98.81	28.00	14.88	91.10	6.89	2.01

	TEXTURE	NH_4-N PPm	NO_3-N PPm	Fe mg/kg	Zn mg/kg	Mn mg/kg	Cu mg/kg	SO4-S mg/kg
PAC-OWL	SILTY LOAM	11.6	0.62	22.05	0.38	0.19	0.416	15.00
PAC - OWR	SANDY LAOM	27.18	4.00	42.38	0.33	0.17	1.07	25.00
PAC NWR	SANDY LAOM	150.01	1.85	12.77	0.28	0.12	0.61	30.00
PAC - NWL	SILTY LOAM	175.78	3.52	3.84	0.06	0.09	0.23	5.00
FRNR-NWL	LOAMY SAND	230.01	42.18	3.87	0.03	0.04	0.25	55.00
FRNR-OWL	LOAMY SAND	230.48	55.26	9.42	0.10	0.03	0.58	15.00
FRNR-OWR	LOAMY SAND	121.91	0.58	15.96	0.12	0.14	0.26	120.00
FRNR-NWR	SAND	120.46	12.89	4.02	0.06	0.03	0.312	30.00

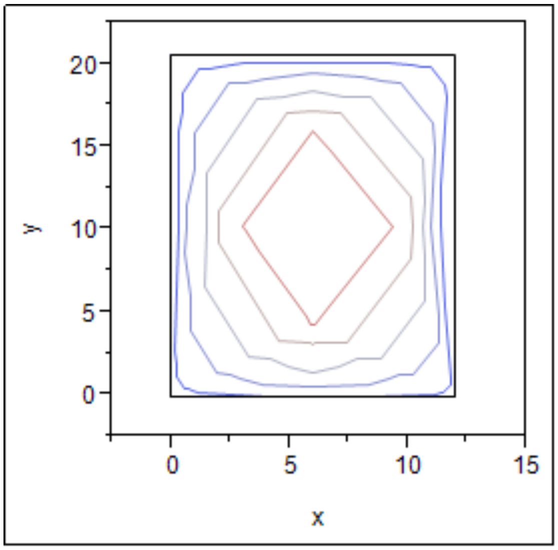
Table 3: *Chlorophyll-a analysis.*

			>665		>750				
DATE	TREATMENT		B/A	A/A	B/A	A/A	chl a	phg	
8/6/2012	PAC - OWL (50ml)	50	0.054	0.033	-0.004	-0.002	1209.3	729.75	meth
8/6/2012	PAC - NWL	50	0.055	0.038	-0.003	-0.001	1209.3	813.15	samp
8/6/2012	PAC - NWL	50	0.067	0.051	-0.02	-0.003	1813.95	1125.9	cell le
8/6/2012	PAC - OWR	50	0.06	0.038	-0.004	-0.005	1334.4	896.55	const
8/13/2012	PAC - NWL	50	0.048	0.033	0	0	1000.8	688.05	
8/13/2012	PAC - OWL	50	0.053	0.032	-0.002	-0.004	1146.75	750.6	
8/13/2012	PAC - OWR	50	0.06	0.034	-0.005	-0.002	1355.25	750.6	
8/13/2012	PAC - NWR	50	0.09	0.058	-0.003	-0.001	1939.05	1230.15	
8/20/2012	PAC- OWL	50	0.043	0.026	-0.001	-0.004	917.4	625.5	
8/20/2012	PAC - NWR	50	0.077	0.049	-0.002	-0.002	1647.15	1063.35	
8/20/2012	PAC - OWR	50	0.041	0.024	-0.003	-0.005	917.4	604.65	
8/20/2012	PAC - NWL	50	0.032	0.02	-0.007	-0.003	813.15	479.55	
8/23/2012	PAC - NWL (50 ml)	50	0.006	-0.001	-0.018	-0.017	500.4	333.6	
8/23/2012	PAC - NWR (50 ml)	50	0.057	0.036	-0.015	-0.014	1501.2	1042.5	
8/23/2012	PAC - OWL (50ml)	50	0.079	0.049	0.002	0.005	1605.45	917.4	
8/23/2012	PAC - OWL (50ml)	50	0.044	0.029	0.001	0.006	896.55	479.55	
8/27/2012	PAC - OWR (50ml)	50	0.083	0.051	0.003	0.001	1668	1042.5	
8/27/2012	PAC - NWR (50ml)	50	0.094	0.057	0.003	0.004	1897.35	1105.05	
8/27/2012	PAC - NWL (50ml)	50	0.047	0.032	0.001	0.004	959.1	583.8	
9/3/2012	PAC - OWL (75ml)	75	0.068	0.039	0.007	0.004	1907.775	1094.625	
9/3/2012	PAC - OWR (50ml)	50	0.124	0.078	0.003	0.008	2522.85	1459.5	
9/3/2012	PAC - NWL (50ml)	50	0.066	0.042	0.004	0.003	1292.7	813.15	
9/3/2012	PAC - NWR (50ml)	50	0.043	0.04	0.003	0.006	834	708.9	
9/10/2012	PAC - OWR (50 ml)	50	0.101	0.076	-0.016	-0.004	2439.45	1668	
9/10/2012	PAC - CP 2 (100ml)	100	0.032	0.019	-0.015	-0.014	1959.9	1376.1	
9/10/2012	PAC - NWR (50 ml)	50	0.108	0.064	-0.015	-0.014	2564.55	1626.3	
9/10/2012	PAC - CP 1 (40ml)	40	0.034	0.021	0.004	0.005	500.4	266.88	
9/10/2012	PAC - NWL (45 ml)	45	0.034	0.022	0.002	0.002	600.48	375.3	
9/10/2012	PAC - OWL (50ml)	50	0.062	0.036	-0.001	0.003	1313.55	688.05	
9/17/2012	PAC - OWR (50ml)	50	0.166	0.115	-0.016	-0.017	3794.7	2752.2	
9/17/2012	PAC - OWL (50ml)	50	0.041	0.016	-0.018	-0.015	1230.15	646.35	
9/17/2012	PAC - OWR (40ml)	40	0.173	0.092	-0.015	-0.013	3135.84	1751.4	
9/17/2012	PAC - NWR (50ml)	50	0.141	0.081	-0.018	-0.015	3315.15	2001.6	
9/17/2012	PAC - NWR (50ml)	50	0.139	0.075	-0.017	-0.016	3252.6	1897.35	
9/17/2012	PAC - CP 2 (50ml)	50	0.024	0.026	0.003	0.013	437.85	271.05	
9/17/2012	PAC - CP 2 (50ml)	50	0.022	0.02	0.001	0.005	437.85	312.75	
9/17/2012	PAC - NWL (50ml)	50	0.083	0.049	0.009	0.005	1542.9	917.4	
9/17/2012	PAC - CP 1 (50ml)	50	0.048	0.029	0.002	0.004	959.1	521.25	
9/17/2012	PAC - OWL (50ml)	50	0.033	0.021	-0.001	0.003	708.9	375.3	
9/17/2012	PAC - NWL (50ml)	50	0.059	0.037	0.002	0.003	1188.45	708.9	
9/17/2012	PAC - CP 1 (50ml)	50	0.054	0.03	0.002	0.001	1084.2	604.65	
9/18/2012	PAC - CP 1 (50ml)	50	0.045	0.026	-0.016	-0.013	1271.85	813.15	
9/18/2012	PAC - CP 2 (50ml)	50	0.007	0.004	-0.013	-0.01	417	291.9	
9/24/2012	PAC - NWL (50 ml)	50	0.084	0.051	-0.015	-0.016	2064.15	1396.95	
9/24/2012	PAC - CP 1 (50 ml)	50	0.051	0.031	0.002	0.002	1021.65	604.65	
9/24/2012	PAC - OWL (50ml)	50	0.027	0.02	0.004	0.005	479.55	312.75	
9/24/2012	PAC - NWR (50ml)	50	0.154	0.103	0.003	0.005	3148.35	2043.3	
9/24/2012	PAC - CP 2 (50ml)	50	0.05	0.013	0.002	0.003	1000.8	208.5	
9/24/2012	PAC - OWR (50ml)	50	0.207	0.135	0.013	0.009	4044.9	2627.1	
9/27/2012	PAC - OWL (50ml)	50	0.016	0.003	-0.017	-0.015	688.05	375.3	
10/4/2012	PAC - OWL	50	0.049	0.031	-0.003	-0.002	1084.2	688.05	
10/4/2012	PAC - CP1	50	0.063	0.041	-0.007	-0.003	1459.5	917.4	
10/4/2012	PAC - NWR	50	0.143	0.092	-0.002	-0.001	3023.25	1939.05	
10/4/2012	PAC - OWR	50	0.121	0.073	-0.003	-0.002	2585.4	1563.75	
10/4/2012	PAC - CP2	50	0.4	0.025	-0.004	-0.003	8423.4	583.8	
10/4/2012	PAC - NWL	50	0.039	0.026	-0.005	-0.002	917.4	583.8	

Table 4: *Summary of pond morphometry.*

Farm	Average Depth(cm)	Area (m^2)	Volume (m^3)
FRNR - NWL	33.8	287	97.0
FRNR - NWR	44.8	1067	477.7
FRNR - OWL	49.0	382	187.4
FRNR - OWR	48.2	888	427.7
PAC - NWL	94.1	248	233.3
PAC - NWR	77.2	248	191.3
PAC - OWL	77.7	248	192.8
PAC - OWR	71.3	248	176.9

PAC - NWL



PAC – OWL

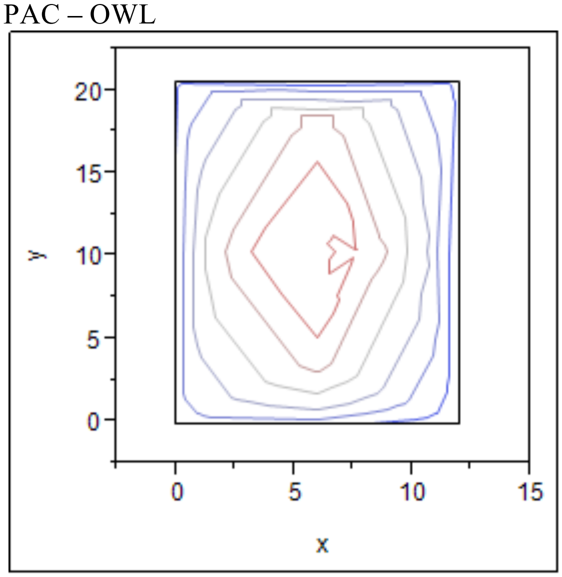
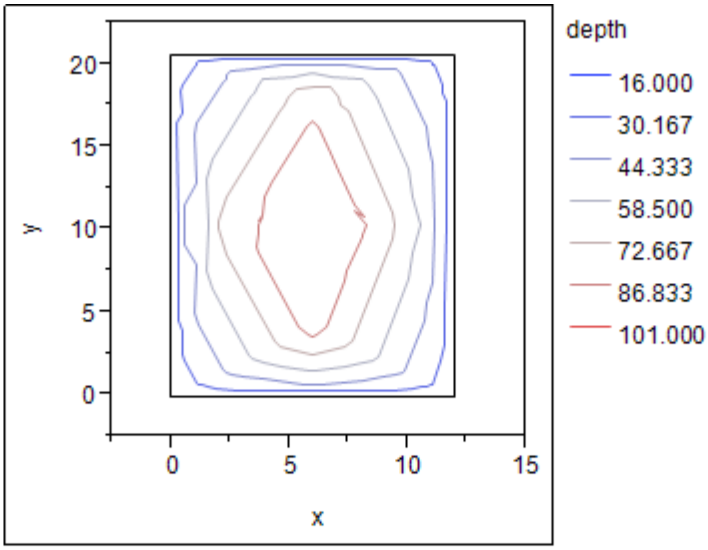


Figure 1a: *Bathymetry of experimental ponds. Depth measurements in centimeters (cm) and pond dimensions are in meters (m). Dimensions are not to scale.*

PAC – NWR



PAC – OWR

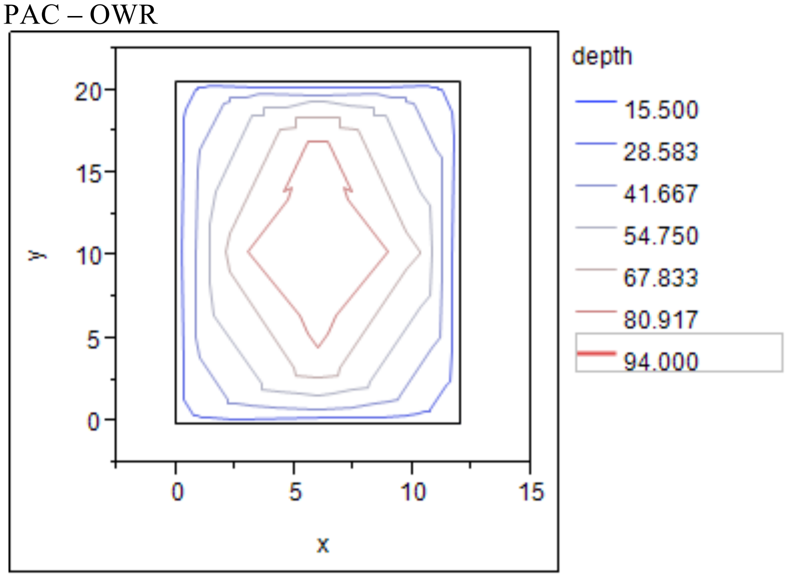
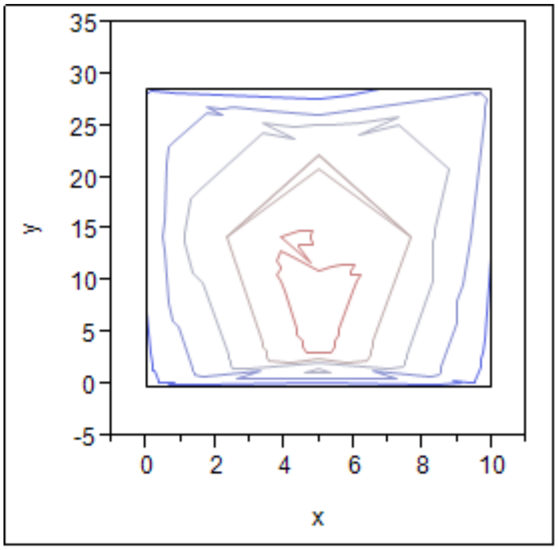


Figure 1b: *Bathymetry of experimental ponds. Depth measurements in centimeters (cm) and pond dimensions are in meters (m). Dimensions are not to scale.*

FRNR – NWL



FRNR – OWL

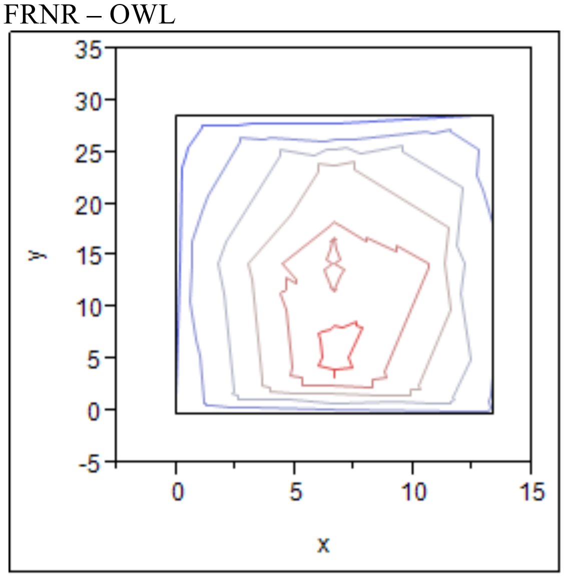
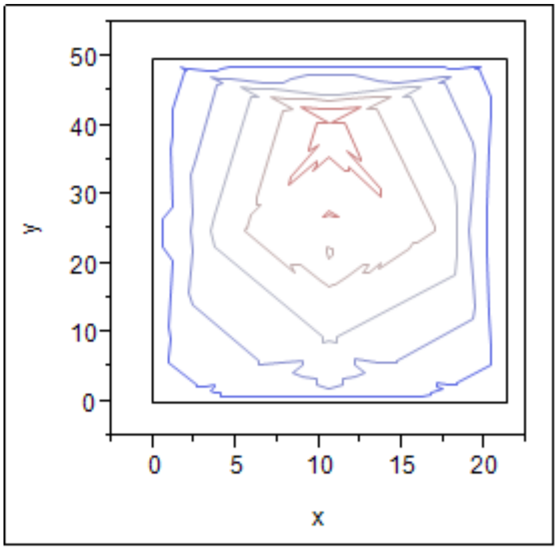


Figure 1c: *Bathymetry of experimental ponds. Depth measurements in centimeters (cm) and pond dimensions are in meters (m). Dimensions are not to scale.*

FRNR – NWR



FRNR – OWR

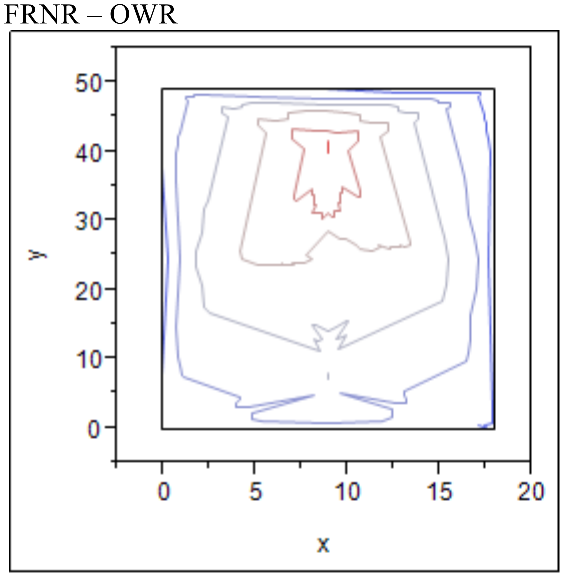


Figure 1d: *Bathymetry of experimental ponds. Depth measurements in centimeters (cm) and pond dimensions are in meters (m). Dimensions are not to scale.*

File attachments:

1. Chlorophyll-a
2. Depth and Evaporation
3. Field water – Temp, pH, DO – (Weekly morning and diel measurements)
4. Lab water – Alkalinity, nutrients, and solids (Weekly measurements)
5. Secchi depth
6. Soil Analysis

ACKNOWLEDGEMENTS

We are grateful to the following students, national service personnel and fisheries officers who participated in various aspects of this study, especially the field work: Francis Adjei, Derrick Owusu, Martha Okai Ababio, Iris Fynn, Yaa Tiwaa Amoah, and Michael Sasu.

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Egna, H.S., N. Brown, and M. Leslie (editors). 1987. Pond Dynamics/Aquaculture Collaborative Research Data Reports, Volume 1, General Reference: Site Descriptions, Materials and Methods for the Global Experiment. PD/A CRSP, Oregon State University, Corvallis, Oregon, 84 pp.

APPENDICES (1, 2):

Appendix 1: Field sampling procedures reviewed and approved prior to commencement of project.

Appendix 2: Laboratory procedures followed for chemical and biological analysis.

APPENDIX 1: FIELD SAMPLING PROTOCOLS REVIEWED AND APPROVED PRIOR TO COMMENCEMENT OF PROJECT

AQUAFISH CRSP EXPERIMENTAL POND UNIT ASSESSMENT (EPUA) PROJECT
Sampling schedule

FRNR-KNUST Farm Diel Pond sampling for the following 3 dates
Dawn of July 10 to dawn of July 11
Dawn of August 21 to dawn of August 22
Dawn of October 2 to dawn of October 3

5:30am	6:00am	9:00am	12:00noon	6:00pm	6:00am
Take water samples (4 small bottles from different locations of each pond)	Temperature (3 depths)	1. Secchi disk depth (5 locations from each pond)	Temperature (3 depths)	Temperature (3 depths)	Temperature (3 depths)
Keep samples in ice chest with ice	Dissolved Oxygen (3 depths)	2. Check water depth	Dissolved Oxygen (3 depths)	Dissolved Ox (3 depths)	Dissolved Ox (3 depths)
	pH (3 depths)	3. Combine portions of water in 4 small bottles to fill one big bottle for each pond. Then combine the rest to fill one small bottle for each pond.	pH (3 depths)	pH (3 depths)	pH (3 depths)
	Alkalinity (3 depths)	4. Analyze chlorophyll-a (this is the small bottle taken from each pond) on FRNR farm	Alkalinity (3 depths)	Alkalinity (3 depths)	Alkalinity (3 depths)

Measure Evaporation.
Note: Deliver 4 big water bottles (labeled) to Kingsley in an ice chest right after the 12:00noon measurements.

PAC Diel Pond sampling for the following 3 dates
Dawn of July 12 to dawn of July 13
Dawn of August 23 to dawn of August 24
Dawn of October 4 to dawn of October 5

6:00am	9:00am	12:00noon	6:00pm	5:30am	6:00am
Temperature (3 depths)	1. Secchi disk depth (5 locations from each pond)	Temperature (3 depths)	Temperature (3 depths)	Take water samples (4 small bottles from different locations of each pond)	Temperature (3 depths)
Dissolved Oxygen (3 depths)	2. Check water depth	Dissolved Oxygen (3 depths)	Dissolved Oxygen (3 depths)	Combine portions of water in 4 small bottles to fill one big bottle for each pond. Then combine the rest to fill one small bottle for each pond.	Dissolved Ox (3 depths)
pH (3 depths)		pH (3 depths)	pH (3 depths)	Keep samples in ice chest with ice	pH (3 depths)
Alkalinity (3 depths)		Alkalinity (3 depths)	Alkalinity (3 depths)		Alkalinity (3 depths)

Measure Evaporation!
Note: Deliver 4 big water bottles (labeled) to Kingsley in an ice chest after measurements. Analyze 4 small water bottles for chlorophyll-a on return to campus.

FRNR Farm Weekly Pond sampling for the following dates
July 18, 25
August 1, 8, 15, 22, 29
September 5, 12, 19, 26

	Activity	**Time**
1	Take 4 small voltic water samples from different points in each pond	6:00am
2	Measure dissolved oxygen	6:00am
3	Record water depths from poles	8:00am
4	Take Secchi disk depth from 5 different locations of each pond	9:00am
5	Combine portions of water in 4 small bottles to fill one big bottle for each pond. Then combine the rest to fill one small bottle for each pond.	After Secchi disk readings
6	Analyze for chlorophyll-a using the water in the small Voltic bottle	After everything is done

PAC Weekly Pond sampling for the following dates
July 16, 23, 30
August 6, 13, 20, 27
September 3, 10, 17, 24

	Activity	**Time**
1	Take 4 small voltic water samples from different points in each pond	6:00am
2	Measure dissolved oxygen	6:00am
3	Record water depths from poles	8:00am
4	Take Secchi disk depth from 5 different locations of each pond	9:00am
5	Combine portions of water in 4 small bottles to fill one big bottle for each pond. Then combine the rest to fill one small bottle for each pond.	After Secchi disk readings
6	Analyze for chlorophyll-a using the water in the small Voltic bottle	After everything is done

APPENDIX 2: LABORATORY PROTOCOLS FOLLOWED FOR CHEMICAL AND BIOLOGICAL ANALYSIS

B3. Total Suspended Solids (TSS)
Procedure
50mL of a well-mixed sample was filtered through a weighed standard glass-fiber filter paper. The residue retained on the filter was then dried in an oven at 103 to 105°C for 1 hour. It was then cooled in a desiccator and weighed. The increase in weight of the filter represents the total suspended solids.

Calculation
The TSS was computed using the formula below:

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

A = weight of filter + dried residue, mg, and

B = weight of filter, mg.

Principle B8. Spectrophotometric analysis

A spectrophotometer is employed to measure the amount of light that a sample absorbs. The instrument operates by passing a beam of light through a sample and measuring the intensity of light reaching a detector. The beam of light consists of a stream of photons. When a photon encounters an analyte molecule (the analyte is the molecule being studied), there is a chance the analyte will absorb the photon. This absorption reduces the number of photons in the beam of light, thereby reducing the intensity of the light beam. The fraction of light in the original beam that passes through the sample and reaches the detector (transmittance) and the amount of light absorbed by the molecules (absorbance) are used in computing the concentration of the absorbing molecule.

In this research, a DR/2400 Spectrophotometer (shown in Plate 1) was used in determining the concentration of Iron, Phosphates, Sulphates, Flourides, Nitrates–nitrogen and Nitrogen– ammonia. The procedures involved are described below:

Plate 1: *DR/2400 Spectrophotometer*

B8.4. Nitrate-nitrogen
Cadmium Reduction Method

Principle
Cadmium metal reduces nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber coloured solution.

Procedure
The concentration of Nitrate-nitrogen was determined by selecting Program 353 N, Nitrate MR from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and the contents of one NitraVer 5 Nitrate Reagent Powder Pillow added to it. The sample cell shaken vigorously to mix the contents and the timer icon pressed to begin a one- minute reaction period. The timer icon is pressed again after the one-minute reaction for a five- minute reaction period to begin. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L NO_3-N.concentration was displayed. After the five-minute reaction period, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of Nitrate-nitrogen was displayed in mg/L NO_3-N.

Nitrite-nitrogen
The method adopted was the Diazotisation method. A measuring cylinder was filled with sample to the 50ml mark and 2ml of sulphanilic acid followed by an equal quantity of 1-napthylamine-7- sulphonic acid. The mixture was allowed to stand for 35 minutes and a pink colour development indicates the presence of nitrite-nitrogen. The concentration of Nitrite-nitrogen was determined using the Hach DR 2400 spectrophotometer. The program number for low range NO_2-N. was entered as 371 and the wavelength was set at 507nm. A 10ml cell was filled with 10ml blank solution and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L NO_2-N concentration was displayed. Another 10ml sample cell was filled with 10mL of the prepared sample and placed in the cell holder of the spectrophotometer after thoroughly wiping

the cell and the 'Read' button was pressed. The concentration of Nitrite-nitrogen present was displayed in mg/L NO_2-N.

Nitrogen-ammonia

Salicylate Method

Principle

Ammonia compounds combine with chlorine to form monochloramine. Monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidized in the presence of a sodium nitroprusside catalyst to form a blue colored compound. The blue color is masked by the yellow color from the excess reagent present to give a green-colored solution.

Procedure

Nitrogen-ammonia was determined by selecting Program 385 N, Ammonia, Salic. from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and another sample cell filled with 10mL deionized water (the blank). To each of these cells, the contents of one Ammonia Salicylate Powder Pillow were added. The cells were stoppered and shaken to mix the contents and the timer icon pressed to begin a three-minute reaction period. After this period, the contents of one Ammonia Cyanurate Powder Pillow were again added to each cell, stoppered and shaken to dissolve the reagent. The timer icon was pressed to begin a 15-minute reaction period. The blank was first placed into the cell holder after the reaction period and the 'Zero' button pressed. A 0.00 mg/L NH_3-N concentration was displayed. Subsequently, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of Nitrogen-ammonia was displayed in mg/L NH_3-N.

TOTAL KJELDAHL NITROGEN

Digestion Of Water Samples With The Macro-Kjeldahl Method

Field of application

The macro-Kjeldahl method is applicable for samples containing either low or high concentrations of organic nitrogen but requires a relatively large sample volume for low concentrations.

General discussion

Nitrogen containing compounds will be converted to NH_4^+. Nitrogen in the form of azide, azine, azo, hydrazone, **nitrate**, **nitrite**, nitrile, nitro, oxime and semi-carbazone **is not included**. If ammonia is not removed in the initial phase the term "Kjeldahl-nitrogen" is applied to the result; if ammonia is removed, the term "organic nitrogen" is applied.

Principle

In the presence of H_2SO_4, K_2SO_4 and $CuSO_4$ catalyst, amino nitrogen of many organic materials is converted to $(NH_4)_2SO_4$. Also NH_3 and NH_4^+ are converted to $(NH_4)_2SO_4$. During sample digestion, a copper ammonium complex is formed and afterwards decomposed by $Na_2S_2O_3$. After decomposition the NH_3 is distilled from an alkaline medium and absorbed in H_2SO_4.

Apparatus

Digestion apparatus

Distillation apparatus

a) Digestion reagent: Dissolve 134 g K_2SO_4 and 11.4 g $CuSO_4.5H_2O$ in about 800 mL H_2O. Carefully add 134 mL conc. H_2SO_4. When it has cooled to room temperature dilute to 1 L. Keep at a temperature close to 20°C to prevent crystallization.

b) NaOH - $Na_2S_2O_3$ reagent: Dissolve 500 g NaOH and 25 g $Na_2S_2O_3.5\ H_2O$ in water and dilute to 1 L.

c) H_2SO_4 0.02 M: Add 1.2 mL conc. H_2SO_4 to 1 L H_2O.

d) Intermediate standard NH_4Cl for Kjeldahl determination.

Digestions

Dilute 50.00 mL stock solution to 1000 mL 1.00 mL = 0.05 mg N.

Procedure

1. Place a measured volume of sample and blank in a Kjeldahl flask, select sample size from the following tabulation. If necessary, add water until about 300 mL. Neutralize to pH 7 in case of strong alkaline samples.

Expected N mg/L in sample	Sample size, mL
0 - 1	500
1 - 10	250
10 - 20	100
20 - 50	50
50 - 100	25
100 - 200	10
200 – 250	5

2. Carefully add 50 mL digestion reagent, mix well and add a few pumice grains

3. Heat in the hood and boil until the volume is about 25 mL and fumes are observed

4. Continue to digest for an additional 30 minutes., coloured or turbid samples will turn clear or straw-colored. **The total destruction time must be at least 4 hours.**

5. Cool, dilute to 300 mL and mix

6. Carefully add 50 mL NaOH-$Na_2S_2O_3$ mixture and connect immediately the flask to the distillation apparatus. Shake the flask to insure complete mixing. A black HgS precipitate will form, the pH should exceed 11.0.

7. Distil and collect 200 mL distillate below the surface of 50 mL 0.02 M H_2SO_4. Extend tip of condenser well below level of H_2SO_4 and do not let temperature in condenser rise above 29°C. **Use a medium high flame and do not lower this flame during the distillation. At the end of the distillation, remove the distillate before the flame is turned off.**

8. Measure the end volume by means of a measuring cylinder and mix.

9. Determine N content of the sample (see procedure 3.2 and start with procedure 3.2.6 step 3).

10. Distillation recovery check: Treat a standard in the same way as the sample by putting 25.00 mL of the intermediate standard solution (=1.25 mg N) in the Kjeldahl flask (as described in step 1).

Measure the end volume by means of a measuring cylinder and mix. Take 10.00 mL distillate and measure the absorbance against mg N **in 50 mL** (see procedure 3.2.6, starting at step 3). Check the distillation recovery.

Remark:

If ammonia should be removed: add 25 mL borate buffer (9.5 gram $Na_2B_4O_7.10H_2O$/800 mL

+ 200 mL 0.1 M NaOH) and 6 M NaOH until pH 9.5 is reached.

Add some pumice and boil off 300 mL. If desired, distill the fraction and determine ammonia nitrogen. Use the residue to determine organic nitrogen.

Reference:
American Public Health Organization. Standard Methods for the examination of water and wastewater, 18th edition 1992. p. 4-95/4-97.

HCO_3^- / CO_3^{2-} ; Alkalinity; Titrimetric analysis

Background

The buffering capacity of water is an important characteristic for water quality. The term alkalinity is also directly involved in water and wastewater unit operations such as water softening, coagulation, iron removal, and pH neutralization. In natural waters, alkalinity may generally be associated with the carbonate equilibrium; most important sources are the atmospheric CO_2 and limestone ($CaCO_3$). At pH ≥ 12, CO_3^{2-} is exclusively present; at pH =8.3 it is all HCO_3^- and at pH ≤ 4.5 it is all CO_2.

Alkalinity is defined as the amount of acid necessary to reach the above equivalence points. Since the first equivalence point, at pH 8.3, often the color indicator phenolphthalein is used, the corresponding alkalinity is referred to as the 'phenolphthalein alkalinity', and the amount of acid necessary to reach pH 4.5 is then called 'total alkalinity'. Metacresol purple can be used as indicator instead of phenolphthalein.

Methyl orange or the mixed indicator bromocresol green-methyl red will be used to detect the second equivalence point at pH 4.5.

For historical reasons, alkalinity is often expressed as mg $CaCO_3$ /L.

Reagents

a) Phenolphthalein indicator: Dissolve 0.5 g in 50 mL ethanol and 50 mL H_2O. b) Metacresol purple indicator: Dissolve 100 mg in 100 mL H_2O.
c) Methyl orange indicator: Dissolve 50 mg in 100 mL H_2O.
d) Bromocresol green- methyl red indicator: Dissolve 100 mg bromocresol green and 20 mg methyl red in 100 mL ethanol.
e) 0.020 N HCl or 0.02 N H_2SO_4 (= 0.01 M H_2SO_4)

Procedure

1. Transfer, with a pipet, a known volume of sample to an Erlenmeyer flask.

2. Add about 5 drops phenolphthalein indicator.

3. In case a red color appears (pH ≥ 8.3) : titrate with 0.020 N HCl until the red color

disappears and record the volume used. Add to the same solution about 5 drops methyl orange or the mixed indicator and titrate until a red color appears. Record the volume used.

4. In case no color will appear (pH ≤ 8.3): add about 5 drops methyl orange or the mixed indicator and titrate until a red color appears, and record the volume used.

Calculations

$$\text{Alkalinity as mg/L } CaCO3 = \frac{V * N * 1000 * 100}{mL\ sample * 2}$$

$$\text{In case initial pH} \leq 8.3 : \text{mg/L } HCO3^{-} = \frac{V * N * 1000 * 61}{mL\ sample}$$

V = titration volume in mL,

N = normality of the acid solution,

100 = molecular mass of $CaCO3^{-}$,

61 = molecular mass of $HCO3^{-}$.

Procedure for determining Chlorophyll-a

Chlorophyll-a analysis was conducted according to the standard procedure described in HMSO (1983). Between 30-50ml of the pond water was filtered under vacuum through a Whatman GF/C filter paper to collect the phytoplankton. The filter paper was placed in a centrifuge tube containing 10ml of methanol. The loosely capped tube was briefly heated in a water bath at 65-70˚C in a fume cupboard. The tube was removed and left for 5 minutes in the dark. The filter paper was removed from the tube after pressing it against the side of the tube to drain as much methanol as possible. The tube was then centrifuged for 8 minutes at 3500rpm to obtain a clear extract for spectrophotometric determination. Absorbance was measured after a baseline correction for methanol at wavelengths of 665nm and 750nm before and after acidification with 0.1M HCl to measure the chlorophyll-a concentration.

Chlorophyll-a concentration in the pond water was determined using the equation below:

$$\textbf{Chlorophyll-a } (\mu g l^{-1}) = 13.9\left(\frac{3(Ah - Aj)\ x\ v}{d\ x\ V}\right)$$

Where Ah = absorbance at 665nm

Aj = absorbance at 750nm

v = initial volume of methanol in ml (usually 10ml)

d = cell length of cuvette in cm (1cm)

V = sample volume in liters (1L)

Reference:
HMSO, 1983. The Determination of Chlorophyll-a in Aquatic Environments. HMSO Publications, London.

TOPIC AREA:
EXPERIMENTAL POND UNIT ASSESSMENT
❖

EXPERIMENTAL POND UNIT ASSESSMENT IN KENYA

Production System Design & Best Management Alternatives /Activity/09BMA11UA

FINAL INVESTIGATION REPORT

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ABSTRACT

Measurements of DO, temperature, conductivity, pH, hardness, TDS, total phosphates, bicarbonates and ammonia were undertaken from 11 February 2013 to 28 February 2013 as a preliminary assessment of the pond units under three fertilizer-feed regimes. The ponds were stocked with all male-tilapia. 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). The preliminary observations 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. Both TDS and conductivity have been shown to be more elevated in fertilized-feed ponds as compared to only fed or fertilized ponds. The preliminary results of the study show promising indications that pond characterization can be done using water quality parameters as a background to enhancing production and implementing BMP.

INTRODUCTION

This pond characterization experiment has two goals;

i) Evaluate ponds at each research site for their physical, chemical, and biological characteristics during grow out, and
ii) To determine the ability of each research site to complete all of these measures.

The methods for pond characterization are well described in a number of publications, including Egna *et al*. (1987) and the *Standard Methods for the Examination of Water and Wastewater* (multiple versions of this are available, the most recent is APHA et al. 2012). The purpose of this report is to report on the preliminary results of a series of measurements that have already been carried out at the University of Eldoret Fish Ponds and the possible implication of these measurements.

METHODS

The preliminary data collected in February 2013 at 12 ponds at the University of Eldoret consisted of 4 control ponds receiving fertilization alone, 4 fully fed ponds with feed applied ad libitum, and 4 combined ponds with both feed and fertilizer applied, feeding at half satiation (as determined in the second treatment).

All ponds were stocked with sex-reversed Nile tilapia (*Oreochromis niloticus*) at 2 fish m^{-2} obtained from Jewlet Farm. Fertilization commenced one week before stocking. Fertilization was done at 4 kg N and 1 kg P per hectare weekly on Saturday, starting one week before stocking, using local nutrient sources that are organic. Feeding was done twice daily at midday and evening. Locally available feeds were used in the experiments.

The feed was prepared on the campus from locally sourced ingredients. The experimental diet consisted of:

Table 1. *Experimental diet.*

Ingredient	**%**	Ingredients were ground in hammer mill to fine flour. Starting in April 2013, we plan to use meat mincer to make pellets.
Wheat bran	50	
Fish meal (*Rastrineobola argentea*)	25	
Cotton seed cake	10	
Sunflower cake	11	
Maize	4	
Total	100	

The feed was determined to have a crude protein content of 30%.

Dissolved oxygen and temperature were measured at two hour intervals from 06:00 to 18:00 daily. Water samples were collected from 5 cm below the water surface at 14:00 each day. Testing was conducted as soon as all the samples were collected in a shaded location avoiding direct sunlight.

Data presented in this report covers the month of February 2013 and spans a period of only 3 weeks. While further measurements are being undertaken and improved, the existing data already show some patterns to report as preliminary observations. At the end of 120 days, data, including yield, growth rate, and survival will be collected for fish from all treatments, and comparisons made using ANOVA. Changes in water quality between treatments and over time will be tested using ANOVA. In addition to chemical concentrations, diel measurements will be used to determine stratification in the ponds and primary productions rates. These will also be compared among treatments using ANOVA. The design and pond treatment is summarized in Table 2 below.

Table 2: *Experimental design of the 12 ponds used in the study.*

POND	DESCRIPTION
B 3	Fertilizer and feeds
B4	Feeds
B5	Fertilizer
B6	Feed s
C3	Fertilizer
C4	Fertilizer and feeds
C5	Feeds
C6	fertilizer
D4	Fertilizer and feeds
D5	Fertilizer
D6	Fertilizer and feeds
D7	Feed

The temporal variation in DO mg L^{-1} for the three treatments show that DO in the fertilizer and feed ponds tracked higher for several of the days as compared to fertilizer alone or feed alone (Fig. 1). These variations were, however, not statistically significant between treatments ($F_{0.05(2), 2,1138} = 0.86$; $p = 0.422$) or in time (($F_{0.05(2), 13,1138} = 1.06$; $p = 0.387$).

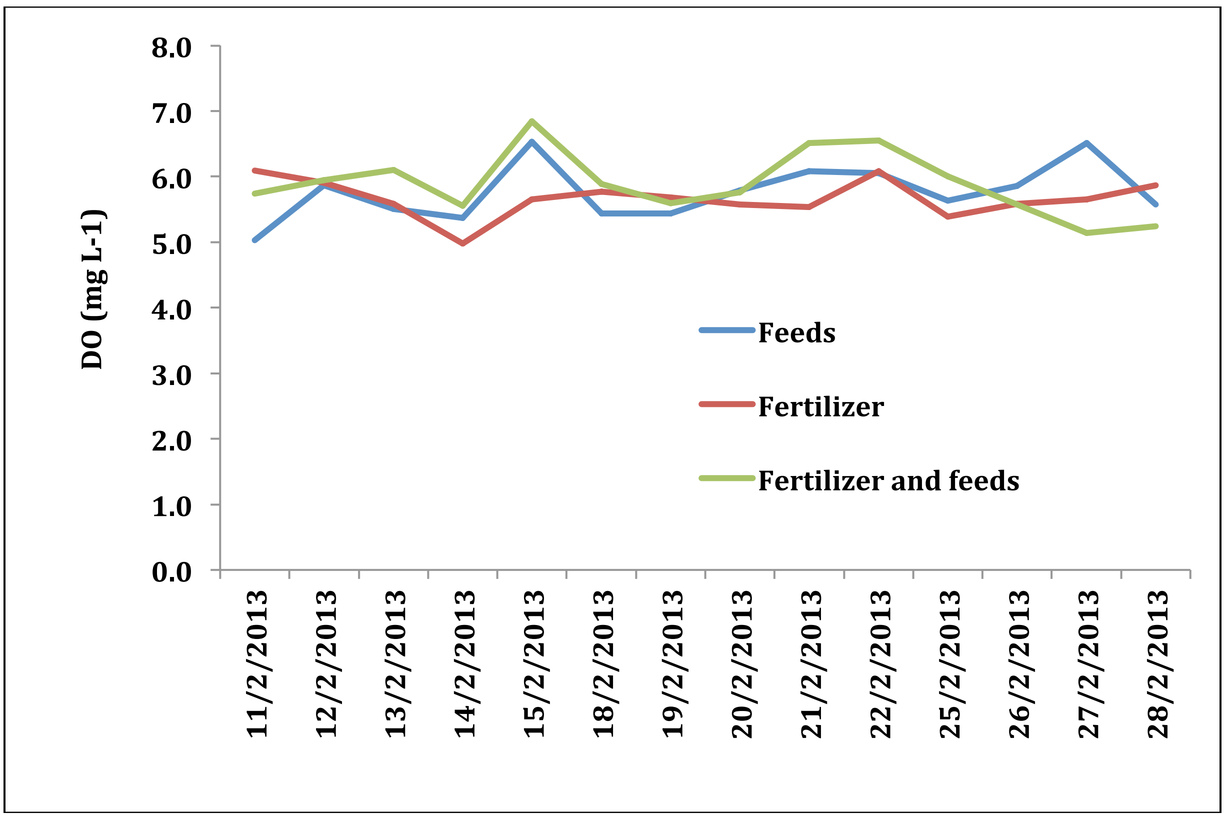

Figure 1: *Daily variations in the dissolved oxygen content for the three treatments.*

The dissolved oxygen showed clear increase from early morning values of about 2 -3 mg L^{-1} at 06:00 Hrs to a maximum of 7-8 mg L^{-1} between 14:00 and 16:00 Hrs (Fig. 2). Variation in the value of DO during the day were statistically significant ($F_{0.05(2), 6,1145} = 2396.25$; $p < 0.0005$) but was not significant between treatments ($F_{0.05(2), 2,1138} = 2.96$; $p = 0.052$). Maximum DO coincided with maximum temperatures and presumably the highest photosynthetic rate, during the same time of the day.

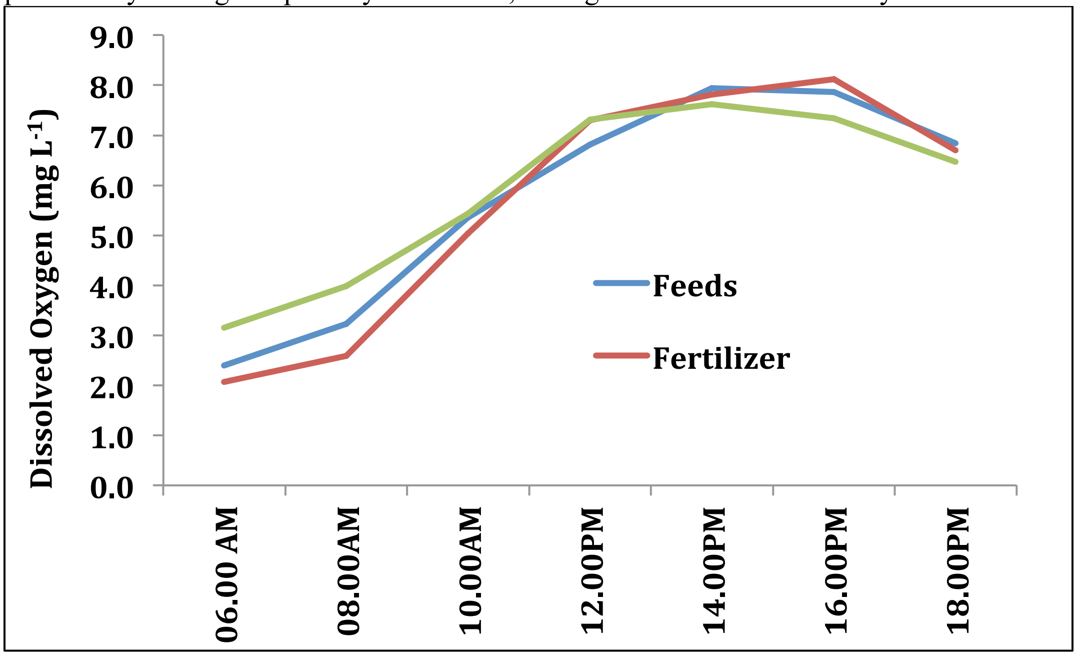

Figure 2: *Variations in the dissolved oxygen content with time of the day for the three treatments.*

The daily temperature variations were not statistically significant between treatments ($F_{0.05(2), 2,1138} = 2.65$; $p = 0.071$) nor between days ($F_{0.05(2), 2,1138} = 1.61$; $p = 0.076$) over the three week sampling period. However, slightly elevated temperatures were reported on 12/2/2013 and slightly depressed temperatures on 25/2/2013 (Fig. 3).

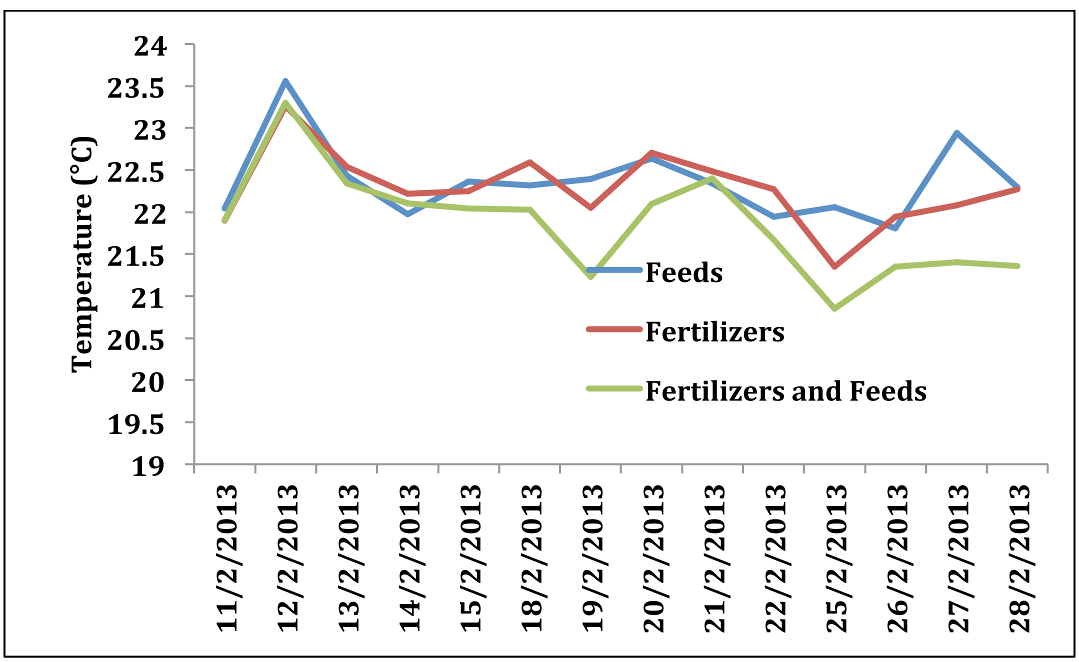

Figure 3: *Daily variations in pond water temperature for the three treatments.*

By-hourly measurements of temperature showed statistically significant variations between treatment ($F_{0.05(2), 2,1145} = 12.40$; $p < 0.0005$) and in time ($F_{0.05(2), 2,1145} = 813.94$; $p < 0.0005$) (Fig. 4). It is apparent that small variations in temperature in the ponds are likely to be responsible for changes in the dynamics of production, depending on the treatment (management) of the fish pond.

Further examination of the ANOVA model showed that there were many observations with large standardized residuals. The standardized residual is the residual divided by an estimate of its standard deviation. This form of the residual takes into account that the residuals may have different variances, which can make it easier to detect outliers. Standardized residuals greater than 2 and less than -2 are usually considered large and unusual. Due to these unusual or different variances, the conclusion that there were significant differences between treatments is treated with caution.

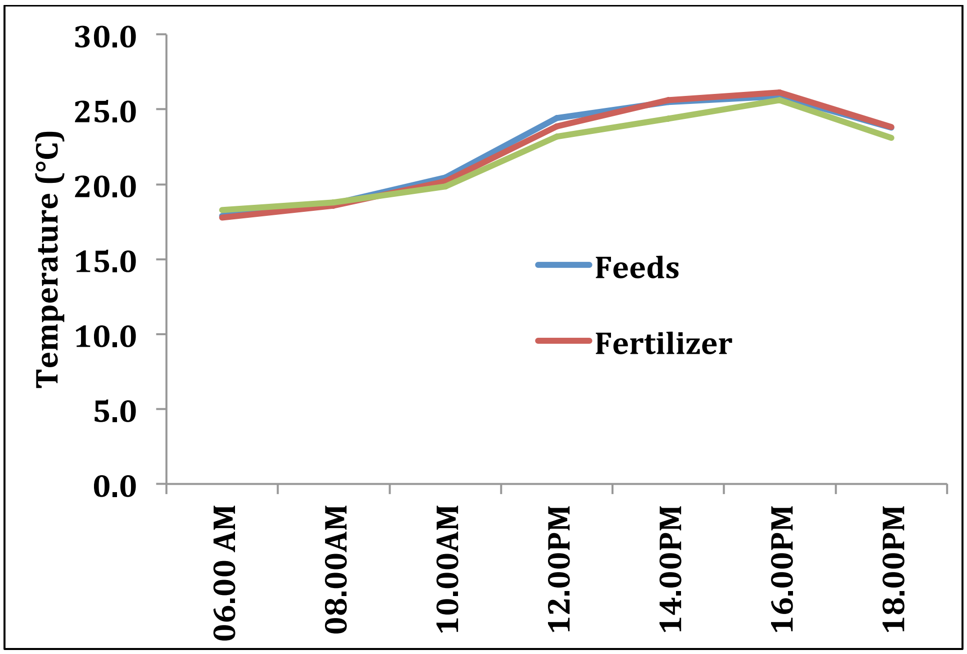

Figure 4: *Variations in pond water temperature with time of the day for the three treatments.*

The variations in conductivity among treatment showed relatively higher values in the fertilized and fed ponds as compared to only fertilized or only fed ponds (Fig. 5) by over 70 units in both cases. Alkalinity was, however, slightly lower in the fertilized and feed ponds as compared to only fertilized or only fed ponds by a range of tens. TDS was higher in fertilized ponds with feeds (263) as compared to only fertilized (217) and only fed ponds (207). Total hardness (44) was relatively lower in the fertilized pond as compared to the two other treatments while the bicarbonates were relatively similar in all treatments.

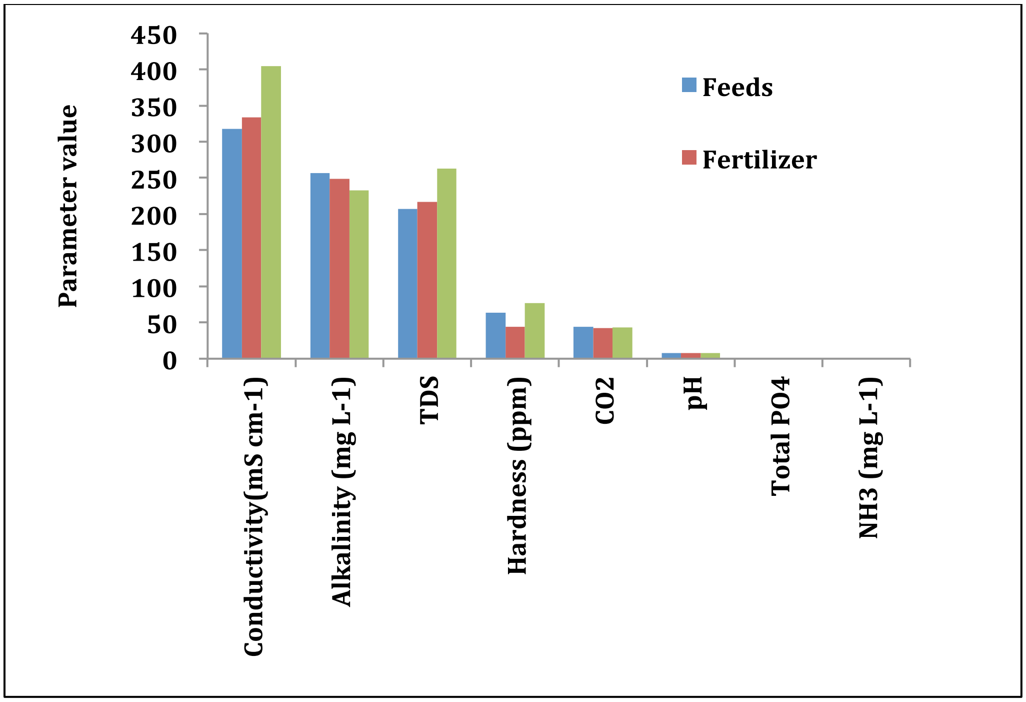

Figure 5. *Variations in selected water quality parameters for the three treatments.*

When the values were considered on a weekly basis, there was a general increase in alkalinity in the pond with fertilizer and feed while the bicarbonates were relatively constant in all treatments and over the weeks (Fig. 6). Both conductivity and TDS were relatively elevated in the pond with fertilizer and feeds as compared to the other treatments (values in week 3 only).

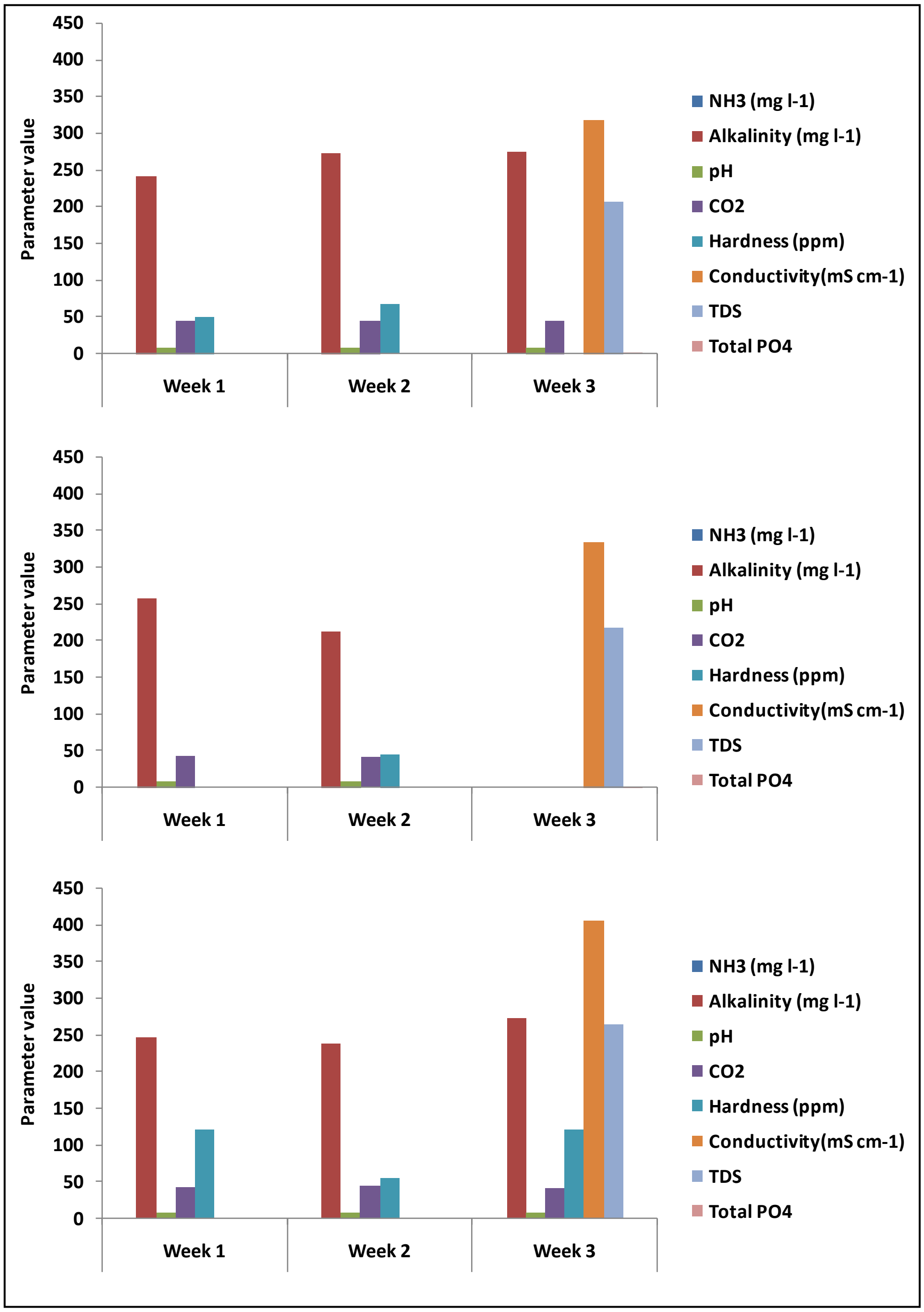

Figure 6. *Weekly variations in selected water quality parameters for the three treatments. Fertilizer, fed and fertilizer and fed, top to bottom, respectively.*

Table 3. *Analysis of Variance (ANOVA) tables for the measured water quality parameter with different treatments.*

General Linear Model: DO versus Treatment, Date

Factor	Type	Levels	Values
Treatment	fixed	3	Feeds, Fertilizer, Fertilizer and feeds
Date	fixed	14	11/2/2013, 12/2/2013, 13/2/2013, 14/2/2013, 15/2/2013, 18/2/2013, 19/2/2013, 20/2/2013, 21/2/2013, 22/2/2013, 25/2/2013, 26/2/2013, 27/2/2013, 28/2/2013

Analysis of Variance for DO, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	2	9.959	10.197	5.099	0.86	0.422
Date	13	81.621	81.621	6.279	1.06	0.387
Error	1138	6717.439	6717.439	5.903		
Total	1153	6809.019				

S = 2.42958   R-Sq = 1.34%   R-Sq(adj) = 0.04%

General Linear Model: DO versus Treatment, Time

Factor	Type	Levels	Values
Treatment	fixed	3	Feeds, Fertilizer, Fertilizer and feeds
Time	fixed	7	06.00 AM, 08.00AM, 10.00AM, 12.00PM, 14.00PM, 16.00PM, 18.00PM

Analysis of Variance for DO, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	2	9.96	11.41	5.71	2.96	0.052
Time	6	4589.02	4589.02	764.84	396.25	0.000
Error	1145	2210.04	2210.04	1.93		
Total	1153	6809.02				

S = 1.38931   R-Sq = 67.54%   R-Sq(adj) = 67.32%

General Linear Model: Temp versus Treatment, Date

Factor	Type	Levels	Values
Treatment	fixed	3	Feeds, Fertilizer, Fertilizer and feeds
Date	fixed	14	11/2/2013, 12/2/2013, 13/2/2013, 14/2/2013, 15/2/2013, 18/2/2013, 19/2/2013, 20/2/2013, 21/2/2013, 22/2/2013, 25/2/2013, 26/2/2013, 27/2/2013, 28/2/2013

Analysis of Variance for Temp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	2	56.78	56.90	28.45	2.65	0.071
Date	13	224.97	224.97	17.31	1.61	0.076
Error	1138	12214.61	12214.61	10.73		
Total	1153	12496.36				

S = 3.27619   R-Sq = 2.25%   R-Sq(adj) = 0.97%

General Linear Model: Temp versus Treatment, Time

Factor	Type	Levels	Values
Treatment	fixed	3	Feeds, Fertilizer, Fertilizer and feeds
Time	fixed	7	06.00 AM, 08.00AM, 10.00AM, 12.00PM, 14.00PM, 16.00PM, 18.00PM

Analysis of Variance for Temp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	2	56.8	51.2	25.6	12.40	0.000
Tme	6	10077.0	10077.0	1679.5	813.94	0.000
Error	1145	2362.6	2362.6	2.1		
Total	1153	12496.4				

S = 1.43646   R-Sq = 81.09%   R-Sq(adj) = 80.96%

NEXT STEPS

The following issues are noted:

1. The project has acquired weather data that will be incorporated in the analysis.
2. The nitrates/nitrites determination seems to be below detectable range and this will be resolved when we acquire the Kjeldahl Unit.
3. Measurement on chlorophyll-a was not possible in February but measurements have commenced in March.
4. Some administrative hitches on procurements are being addressed.

TOPIC AREA:
EXPERIMENTAL POND UNIT ASSESSMENT

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EXPERIMENTAL POND UNIT ASSESSMENT IN CAMBODIA

Production System Design & Best Management Alternatives/Activity/09BMA12UC

FINAL INVESTIGATION REPORT

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INTRODUCTION

In Cambodia, fish provide a main source of protein and essential nutrients of daily diet for millions of people, especially for the poor households in rural areas and also contribute to the national economy. Fish account for more than 75 percent of people's animal protein intake (Ahmed et al. 1998; So Nam and Buoy Roitana, 2005). The national fish consumption rate is an average of 23-31kg $capita^{-1}$ $year^{-1}$ (So Nam and Nao Thuok 1999). Fish consumption and export are mainly supplied by fish catches from inland waters. Since wild fish catches have dramatically declined from year to year due to illegal and overfishing and fish demand has also increased in response to rapid population growth, the aquaculture sector has been promoted in the country.

Eighty percent of aquaculture production comes from cages and pens in Tonle Sap Great Lake, Tonle Sap, Mekong and Bassac River systems (Mekong River Commission 2002). The commercial species cultured in cages include the river catfish *Pangasianodon hypophthalmus* and giant snakehead *Channa micropeltes*. Raising fish in ponds and paddy fields is less developed in Cambodia (MRC, 2002), contributing about 15-20 percent of total aquaculture production. Since 2005, small-scale aquaculture has been jointly promoted and supported by the government, NGOs, and international agencies (e.g. JICA, PADEK, AIT, etc.) for the poor and in the areas far away from natural water bodies, which lack fish consumption. The small-scale cultures are mainly in ponds, rice fields, and integrated fish farming with livestock and vegetables. The main species cultured in those systems, particularly in ponds, include Tilapia, Chinese carp, Indian carp, and some indigenous species (e.g. silver barb, walking catfish, river catfish). Currently, pond culture has increased in number and may play an important role in aquaculture development throughout the country in the future. Pond characteristics, physical, chemical and biological factors, interact in pond ecosystem as well as the organisms being culture (Egna & Boyd, 1997). Water quality in fish ponds is a major factor determining the production of fish (Egna and Boyd, 1997). Evaporation and seepage contribute to the water losses from the pond, resulting in higher densities of fish in the pond which can lead to various water quality problems (Egna and Boyd, 1997), causing stress to fish or direct mortality and lowering the production per cycle. The studies of pond characterization, water quality, nutrient cycling, and water use in pond aquaculture have been done in many parts of the world. For example, in the neighboring countries like Thailand and Vietnam, many studies in the field of aquaculture have been done and their aquaculture sectors have rapidly developed. So far Cambodia's aquaculture is less developed because of lack of research and study has been conducted and lack of experts of this field. So, it is necessary to conduct research on physical, chemical, and biological characteristics of aquaculture pond during growth out since it may contribute to aquaculture development in Cambodia.

The purpose of this experiment was firstly to evaluate ponds in Southern Cambodia for their physical, chemical, and biological characteristics during a growth-out period from June to October 2012.

METHODS AND MATERIALS

This experiment was carried out at Freshwater Aquaculture Research and Development Center (FARDeC), Prey Veng, Cambodia, from June 15 to October 15, 2012. The experiment was conducted in twelve 300 m^2 earthen ponds with an average depth of 1m using the Gift tilapia *Oreochromis niloticus* (Annex A).

Three treatments were allocated in twelve earthen ponds to test effects of different feeding inputs. The first treatment was the application of chemical fertilizers alone (Urea 46%N and DAP 18%N, 46%P), the second treatment was the application of pellet feed alone (commercial Tilapia feed), and the third treatment was the combination with both chemical fertilizers and pellet feed (feeding 50% satiation of the second treatment).

Fingerlings of the Gift tilapia both male and female (average 2.5g size) were stocked at 2 fish m^{-2} in all earthen ponds on 15 June 2012. During the experiment, average weights of gift tilapia were determined monthly in each pond. Twenty fish were randomly sampled by seine net for determining average weight and immediately returned to the water in each pond. Gift tilapias in every pond were harvested, counted, and bulk weighed on 15 October 2012 after 120 days of culture. Growth (g fish $^{-1}$), mean weight gain (g fish^{-1}), daily weight gain (g fish $^{-1}$ d^{-1}), specific growth rate (%), gross yield (kg pond^{-1}per 120 days), and extrapolated gross yield (kg pond^{-1} year^{-1}) were calculated.

The ponds were fertilized weekly with urea and di-ammonium phosphate (DAP) at 4 kg N and 1 kg P ha^{-1} d^{-1} (with approximate-calculated amount of 1.47 kg of urea and 1.0 kg of DAP pond^{-1} for one week of application), suspending in a porous bag in the middle of the pond within the top 25 cm of the water column. Initial pond fertilization took place one week prior to stocking fish. Water depths in the pond were regularly maintained at 1.0 m throughout the experiment by adding water weekly to replace seepage and evaporation losses. The pond water depths, seepage, and evaporation, including rainfall, were recorded on a weekly basis. Evaporation pan with 150 cm diameter and 50 cm depth was used to estimate water loss to evaporation. Evaporation loss from the pond was calculated by multiplying level of water loss in evaporation pan with its coefficient of 0.75 (Boyd, 1990). Staff gauge was installed in each pond to monitor water level change in weekly basis. Seepage was estimated by taking the difference between water level changes in water depth and evaporation loss. Since rainfall was negligible during sampling period of the first five weeks of the experiment, rainfall was assumed zero.

Floating pellet feed containing 35% crude protein was introduced to fish at feeding rate of 8% of fish body weight per day from stocking until one month period, and then, in the second month until harvest, feed composition and feeding rate were adjusted to 25% crude protein and 3% of body weight, respectively. Fish was fed two times a day at 0900-1000h and 1500-1600h. Total amount of feed added to each pond was recorded for estimating food conversion ratio (FCR).

Composite water samples were collected from the entire water column near the two ends and the center of the pond weekly at approximately 0800h. Then samples were mixed in a plastic bucked and 1 liter sample was taken as a representative water sample and sent to water laboratory for total Kjeldahl nitrogen (TKN), total phosphorus (TP), and chlorophyll a analyses. Analyses were done for TKN, TP and chlorophyll-a at laboratory using standard methods (Clesceri L.S *et al*., 1998). Then at 1400h on the same day, composite water samples were collected again for alkalinity, ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3) analyses on site using test-kits (Manufacturer: sera GmbH made in Germany and Azoo made in Taiwan). All water samples were collected every five days after fertilization. At the second water sampling, Secchi disk visibility was measured using a Secchi disk, while temperature, dissolved oxygen (DO) and pH were measured with a 2-ch. DO/pHMeter DOP-5F (Kasahara Chemical Instruments Corp.). Diel measurements for temperature, DO, pH, and alkalinity were conducted monthly at three depths (25 cm below water surface, middle, and 25 cm above bottom) in each pond at 0600h, 1200h, 1800h, 2400h, and 0600h at regular time. DO was also measured weekly at dawn (0600h) in each pond.

One-way ANOVA was used to test the effect of the treatments on mean values of fish yield, growth, survival, including changes in water quality between treatments and overtime with SPSS (version 16.0) statistical software package (SPSS Inc., Chicago, Illinois, USA). Differences were considered significant at an alpha of 0.05.

RESULTS

Survival of gift tilapia in ponds ranged from 46.2 to 84.3% (Table 1), with the highest in pond applied fertilizers then feed, and the lowest in pond applied fertilizers alone; and there were significant differences among the treatments. Survival was significantly lower in fertilizer treatment than the other two treatments ($P<0.05$, Table 1), while for both the other treatments it was similar ($P > 0.05$). Tilapia growth was significantly greater with fertilizers plus feed treatments than the other two treatments ($p<0.05$), showing only at first month of sampling period (Figure 1). However, growth was not significantly different among the treatments in the second and third month of sampling ($p > 0.05$). At harvest, while at harvest tilapia growth was significantly higher only in fertilizer plus feed treatment than in the fertilizer treatment (Table 1; Figure 1), while that for feed treatment was similar among other two treatments ($p>0.05$). The highest growth was seen in fertilizer and feed treatment (149.6 g $fish^{-1}$), and the lowest in just fertilizers (87.2 g $fish^{-1}$, Table 1). Gross yield of pond gift tilapia in ponds ranged from 24.6 to 73.6 kg $pond^{-1}$ per 120 days; and significantly differed among the treatments ($p<0.05$, Table 1), with the highest value in the fertilizers then feed (73.6 kg $pond^{-1}$per 120days), the lowest in the fertilizer treatment (24.6 kg $pond^{-1}$per 120days), and intermediate in the feed (55.9 kg $pond^{-1}$ per 120 days).

Mean daily weight gains and specific growth rate (SGR %) in fertilizers combined feed treatment were significantly greater than those in the chemical fertilizer treatment ($p<0.05$, Table 1), while there was not significantly different between feed with other two treatments ($p> 0.05$, Table 1).

The feed conversion ratio was significantly better in fertilizers plus feed treatment than that in the feed alone ($p<0.05$, Table 1).

As shown in Table 2, pond water depth, evaporation, and seepage losses did not significantly differ among the treatments ($p>0.05$); and half of water quality parameters showed no significant differences among treatment which included dissolved oxygen at dawn, pH, alkalinity, ammonia chlorophyll a and Secchi disk visibility ($p > 0.05$); and other half of water quality parameters showed significant differences among treatments, including temperature, dissolved oxygen at 1400h, total Kjeldahl nitrogen, total phosphorus, nitrite, and nitrate ($p < 0.05$). Mean values of temperature in the fertilizer treatment were significantly lower than those in other two treatments (feed and fertilizers then feed, both did not significantly differed). Temperatures were also significant differences and fluctuated over culture period for all treatments. Mean temperatures ranged from 28.7- 33.6^{o}C (Table 3), 28.3-32.7 ^{o}C (Table 4), 28.8-33.6 ^{o}C (Table 5), and 29.0-33.8 ^{o}C (Table 6) for overall mean, fertilizers, feed, fertilizers then feed treatments, respectively. Mean dissolved oxygen at dawn (0600 h) did not significantly differ among the treatments ($p > 0.05$); while it was significant at 1400 h only between feed and fertilizers then feed treatments (significantly higher; $p < 0.05$, Table 2); and both DO at dawn and DO at 1400 h were significant differences ($p<0.05$) and fluctuated over culture period for all treatments (Figure 2 & 3). Mean dissolved oxygen at dawn and at 1400 h, respectively, ranged from 1.0 -2.7 mg l^{-1}; 4.3-8.7 mg l^{-1}(Table 3), 0.8-2.9mg l^{-1}; 4.3-10.8 mg l^{-1} (Table 4), 0.9-2.6mg l^{-1}; 3.7-6.8 mg l^{-1} (Table 5), and 1.0-2.6mg l^{-1}; 4.0-10.9 mg l^{-1} (Table 6) for overall, fertilizers, feed, and fertilizers then feed treatments, respectively. Nutrient concentrations, TKN, NO_3 and TP, were significantly lower in the feed treatment than other two treatments ($p<0.05$, Table 2). NO_2 was only significantly lower in the feed treatment than in fertilizers ($P<0.05$). TKN and TP also significantly differed and fluctuated over culture period for all treatments ($p<0.05$, Figure 4 & 5). Mean values of TKN and TP, respectively, ranged from 1.0-6.1mg l^{-1}; 0.6-2.7mg l^{-1} (Table 3), 1.3-7.8mg l^{-1}; 0.8-2.8mg l^{-1} (Table 4), 0.4-3.6mg l^{-1}; 0.2-1.2mg l^{-1} (Table 5), and 0.8-9.3mg l^{-1}; 0.6-3.9mg l^{-1} (Table 6) for overall, fertilizers, feed, and fertilizers then feed treatments, respectively. Chlorophyll-A concentrations and Secchi disk visibility were not significant among the treatments (Table 2).

Mean values of pH and alkalinity did not significantly differ among the treatments ($p> 0.05$, Table 2), while they were significantly different and fluctuated overtime for all treatments ($p<0.05$). Values of Alkalinity at the beginning of the experiment were significantly higher than those at the end ($p< 0.05$, Figure 6).

Mean values of pH and alkalinity, respectively, ranged from 5.1-8; 44.8-79.1mg l^{-1} (Table 3), 4.7-8.4; 40.3-85mg l^{-1} (Table 4), 4.8-7.4; 40.3-80.6mg l^{-1} (Table 5), and 5.8-8; 44.8-85mg l^{-1} (Table 6) for overall, fertilizers, feed, and fertilizers then feed treatments, respectively.

DISCUSSION

The results of the present study indicated that fertilized ponds supplemented 50% satiation feeding had significant influence on the growth rate, survival and production of pond tilapia, compared to non-feeding ponds. Although growth rate and survival of tilapia for fed-only treatment and fertilizer plus feed treatment were similar, the production and food conversion ratio of tilapia in fertilized ponds with supplemental feeding were significantly better than those in fed-only ponds. The present study supports the results reported by (Green, 1992; Diana et al., 1994; Yi & Lin, 2001; Waidbacheret al., 2006; Liti et al., 2005; Thakur et al. 2004). Diana et al. (1994) demonstrated that feed and fertilizer combination was more effective in the production of *O. niloticus* than fed-only treatments and attributed the better growth of tilapia to high abundance of natural food and improved water quality. Green (1992) also presented results indicating that food conversion ratio was better in feed and fertilizer combination than fed-only ponds. In this study, although the production of tilapia in non-feeding pond (fertilizer-only) was significantly lower than that in fed-only pond which is probably because of low survival rate in the non-feeding, the growth rate for both treatments was similar. This may be supported by findings of Yi & Lin (2001), indicating that natural foods were abundant and important to growth in non-feeding ponds. Waidbacher et al. (2006) quoted that fertilizer plays two major roles in semi-intensive production of tilapia: it improves fish nutrition through stimulation of natural food (Schroeder et al., 1990), and dissolved oxygen levels through photosynthesis, while ammonia levels are reduced through assimilation by phytoplankton (Boyd 1990). De Silva (1993) indicated that natural food contains high-quality protein, which ranges between 55% and 60% on dry weight basis, but less energy content. Utilization of natural food of tilapia may decrease with increasing availability of artificial feed, giving higher FCR in the treatment (Yi & Lin, 2001). Combination of fertilizers supplemented feed at a lower percentage of satiation makes tilapia more efficient at utilizing natural foods and nutrients (Green, 1992; Diana et al., 1994, 1996; Yi & Lin, 2001). Diana et al. (1994) and Yi & Lin (2001) reported that feeding rate could be reduced by 50% of satiation level which resulted in low FCR, good growth and yield performance, high economic return, and potential for growing to greater size. This was also realized in the present study.

Growth value of tilapia under fertilizers plus feed treatment in the present study was 1.2 g fish^{-1}d^{-1}, which realizes lower growth rate than the values of 2.11 g fish^{-1}d^{-1}(Yi & Lin, 2001); 3.10 g fish^{-1} d^{-1} (Diana et al., 1996); and 1.8 g d^{-1} (Thakur et al. 2004), might be due to the low abundance of natural food to supplement tilapia growth in such ponds as reflected by lower concentration of chlorophyll a for all treatments in the present study, caused by clay turbidity from weekly addition of water for replacing seepage and evaporation losses. In the experiment, water was supplied by pumping directly from Mekong River during flooding season which clay turbidity presented in the water. Another reason for lower growth rate in the study, since tilapia were stocked both male and female, was reproduction. Tilapia might also use some of energy for their reproduction in the present experiment. The reproduction of tilapia had been seen at the second month of fish sampling when size reached 30-50g. However, the growth rate is slightly higher than the values of 0.64 g d^{-1}(Waidbacher et al., 2006); 0.34 g d^{-1} (Liti et al., 2005) in Kenya; and 0.74 g d-1 (Naggar et al., 2008) in Egypt under fertilization plus feeding. Net annual fish yield (7210 kg ha^{-1} yr^{-1}) of tilapia under fertilizer plus feed treatment in this study was lower than the yield range (8400 and 11,600 kg ha-1 yr-1), and (10,400- 17,200 kg ha^{-1} yr^{-1}) stocking at 3 fish m^{-2} reported (Diana et al., 1994; Thakur et al. 2004) in a fertilizer and supplemental feeding combination feed at 50% *ad libitum*. The present yield was comparable to the values of 7272 kg ha^{-1} yr^{-1}; 8856 kg ha^{-1} yr^{-1} in fertilizer plus feed treatment reported by (Green et al., 2002; Liti et al., 2005, respectively); and higher than the values of 6800 kg ha^{-1} yr^{-1} (Naggar et al., 2008); and 4284 kg ha^{-1} yr^{-1}(Waidbacher et al., 2006).

Major physical, chemical and biological parameters measured during the study expressed in the favorable range for Tilapia culture. Mean value of evaporation loss was 3.5 mm day^{-1} in the present study which is in the ranges of 2.7-6.3 mm day^{-1} (Gross, 2000; Verdegem et al., 2006); and 1.7-6.0 mm day^{-1} reported by (Yoo & Boyd., 1994) for ponds in the USA, depending on location and temperature. Verdegem & Bosma (2009) reported evaporation loss from ponds was in average of 4.2 mm day^{-1} (1,500 mm yr^{-1}), which is comparable to the present study. Green & Boyd (1994) indicated that high evaporation is due to a combination of high solar radiation, low humidity and stronger winds. Mean values of seepage losses ranged 2.7-4.5 mm d^{-1}which was lower than that in the ranges of 5-10 mm day^{-1} for a combination of bottom percolation and lateral seepage losses (Boyd, 1994). While Boyd (1982) reported the range of 0-90 mm day^{-1}, Verdegem et al. (2006) reported seepage loss on average was 5.5 mm day^{-1}(2000 mm yr^{-1}). Mean values of major water quality parameters in this study were comparable to those reported by (Yi & Lin, 2001; Thakur et al 2004), except chlorophyll a concentration was lower, might be due to the presence of clay turbidity or suspended solid in replacement water every week.

In conclusion, this study revealed that pond with fertilization plus supplementary feeding (50% satiation) was the most effective feeding for optimization of production, feed conversion ratio, and growth performance of tilapia culture for semi-intensive system or small-scale aquaculture.

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List of Tables

Table 1. *Growth (g fish^{-1}), yield (kg pond^{-1} 120d^{-1}; kg pond^{-1} yr^{-1}), survival (%) and FCR, SGR (%) of Gift Tilapia stocked in 300-m^2 pond during the 120 day grow-out under the three treatments.*

Performance Measures	**Treatments**		
	Fertilizers *(n=4)*	**F**eed *(n=4)*	**F**ertilizers+ **F**eed*(n=4)*
STOCKING			
Density (fish m^{-2})	2	2	2
Total Number (head)	600	600	600
Total Weight (kg pond^{-1})	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0
Mean Weight (g fish^{-1})	2.5 ± 0.0	2.5 ± 0.0	2.5 ± 0.0
HARVEST			
Total Number (head)	277 ± 19^a	504 ± 47^b	506 ± 26^b
Total Weight (kg pond^{-1})	24.6 ± 3.6^a	55.9 ± 3.5^b	73.6 ± 3.7^c
Mean Weight (g fish^{-1})	87.2 ± 6.9^a	113.0 ± 9.5^{ab}	146.9 ± 11.9^b
Mean Weight Gain (g fish^{-1})	84.7 ± 6.9^a	110.5 ± 9.5^{ab}	144.4 ± 11.9^b
Daily Weight Gain (g fish^{-1} d^{-1})	0.7 ± 0.1^a	0.9 ± 0.1^{ab}	1.2 ± 0.1^b
Gross yield (kg pond^{-1}120d^{-1})	24.6 ± 3.6^a	55.9 ± 3.5^b	73.6 ± 3.7^c
Gross Yield (kg pond^{-1} yr^{-1})	73.7 ± 10.8^a	167.6 ± 10.4^b	220.8 ± 11.2^c
Net Yield (kg pond^{-1} yr^{-1})	69.3 ± 10.8^a	163.2 ± 10.4^b	216.3 ± 11.2^c
Gross Yield (kg ha^{-1} 120d$^{-1)}$	818.3 ± 119.8^a	1862.5 ± 115.2^b	2453.3 ± 124.0^c
Gross Yield (kg ha^{-1} yr^{-1})	2455.0 ± 359.4^a	5587.5 ± 345.6^b	7360.0 ± 372.0^c
Net Yield (kg ha^{-1} yr^{-1})	2310.0 ± 359.4^a	5440.0 ± 345^b	7210.0 ± 372.0^c
Total feed amount (kg)	---	117.6 ± 0.0^a	58.8 ± 0.0^b
FCR	---	2.2 ± 0.1^a	0.8 ± 0.1^b
SGR (%)	3.0 ± 0.1^a	3.2 ± 0.1^{ab}	3.4 ± 0.1^b
Survival (%)	46.2 ± 3.1^a	84.0 ± 7.8^b	84.3 ± 4.3^b
	(41-53)	(67-99)	(72-92)

Mean (± SE) values with different superscript letters in the same row were significantly different among treatments (P < 0.05); n= number of replicated ponds.

Table 2. *Water depth, seepage and evaporation losses, including water quality parameters measured weekly in the pond at 1400 h (except DO at dawn; 0600 h) during 120- day grow-out under different treatments.*

Parameters	**Treatments**		
	Fertilizers *(n=4)*	**F**eed *(n=4)*	**F**ertilizers+ **F**eed*(n=4)*
Pond water depth (cm week^{-1})	4.4 ± 0.3	5.3 ± 0.4	5.7 ± 0.5
Evaporation (cm week^{-1})	2.5 ± 0.0	2.5 ± 0.0	2.5 ± 0.0
Seepage (cm week^{-1})	1.9 ± 0.3	2.8 ± 0.4	3.2 ± 0.5
Temperature (^{o}C)	30.7 ± 0.1^a	31.6 ± 0.1^b	31.2 ± 0.2^b
DO (mg l^{-1})	6.9 ± 0.7^{ab}	5.5 ± 0.4^a	7.9 ± 0.7^b
DO at dawn (mg l^{-1})	1.4 ± 0.1	1.5 ± 0.1	1.8 ± 0.2
pH	7.1 ± 0.3	6.7 ± 0.2	7.3 ± 0.2
Alkalinity (mg l^{-1} as $CaCO_3$)	56.9 ± 1.0	57.7 ± 1.5	55.3 ± 0.9
TKN (mg l^{-1})	4.5 ± 0.5^a	1.4 ± 0.1^b	4.1 ± 0.1^a
NH_3 (mg l^{-1})	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
NO_2 (mg l^{-1})	2.4 ± 0.4^a	0.3 ± 0.2^b	1.4 ± 0.4^{ab}
NO_3 (mg l^{-1})	34.2 ± 4.7^a	0.8 ± 0.2^b	23.8 ± 3.6^a
TP (mg l^{-1})	2.0 ± 0.3^a	0.5 ± 0.1^b	1.3 ± 0.1^c
Chlorophyll- a (µg l^{-1})	36.0 ± 5.5	20.9 ± 2.7	46.0 ± 10.1
Secchi Disk Visibility (cm)	24.2 ± 3.5	27.0 ± 1.6	22.3 ± 1.8

Mean (± SE) values with different superscript letters in the same row were significantly different among the treatments (P<0.05); n= number of replicated ponds.

Table 3. Overall mean values (n=12) of water quality parameters weekly measured at 1400 h (except DO at dawn) during the culture period.

Parameters	**Culture Week**																
Overall (n=12)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
*Temperature(ºC)	29.3	28.7	30.9	30.3	32.2	31.0	30.7	31.5	31.6	33.6	32.9	30.8	32.8	30.7	30.7	30.5	31.2
*DO (mg l^{-1})	6.9	6.6	6.8	6.9	7.3	7.2	8.4	5.5	6.7	8.2	8.7	5.7	8.7	6.4	4.3	6.9	6.8
*DO (mg l^{-1}) dawn	---	---	---	---	2.7	2.2	2.0	1.0	1.6	1.3	1.7	1.2	1.4	1.6	1.0	1.2	1.3
*pH	7.7	7.5	8.0	7.5	6.5	7.0	6.9	---	6.7	7.1	7.3	5.1	---	---	---	7.4	---
*Alkalinity (mg l^{-1})	76.0	59.7	79.1	62.7	61.2	56.7	59.7	58.2	53.7	47.7	55.2	55.2	50.7	49.2	47.7	44.8	44.8
*TKN (mg l^{-1})	1.0	3.4	1.6	1.8	1.1	3.3	3.6	5.6	1.9	3.2	3.7	3.9	6.1	4.9	4.9	5.2	1.9
NH_4 (mg l^{-1})	0.4	1.0	0.8	2.0	1.8	1.0	0.7	0.7	0.9	0.6	0.5	1.0	0.4	0.4	0.4	0.2	0.3
NO_2 (mg l^{-1})	0.9	0.9	0.9	0.9	1.3	1.3	1.0	2.0	1.6	1.4	2.4	1.4	1.8	1.4	1.7	0.2	0.7
NO_3 (mg l^{-1})	15.0	15.0	14.6	15.8	9.2	10.8	15.0	27.9	27.5	24.6	21.7	29.6	23.8	23.8	21.7	8.3	17.5
*TP (mg l^{-1})	0.7	0.9	0.6	0.7	1.2	1.7	1.0	1.2	0.9	0.8	1.1	2.3	1.5	1.9	1.4	2.7	1.1
*Chlophyl a(µgl^{-1})	38.2	29.2	26.8	31.8	39.5	36.9	25.6	63.0	28.4	50.6	59.5	21.7	29.2	45.7	30.4	17.7	10.6
*SDD (cm)	43.7	28.2	22.8	24.0	22.2	20.0	23.5	19.0	26.1	23.4	23.6	21.0	22.0	20.9	24.9	25.0	26.6

Parameters marked with an asterisk (*) had significant differences among the time periods.

N= number of ponds

T= treatment

SDD= Secchi disk depth (visibility)

Table 4. *Mean values (n=4) of water quality parameters in fertilizer treatment (T_1) weekly measured at 1400 h (except DO at dawn) during the culture period.*

Parameters	**Culture Week**																
T_1 (N=4)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
*Temperature(°C)	29.0	28.3	31.0	29.8	31.2	30.2	30.1	31.0	31.0	32.7	32.5	30.4	32.6	30.4	30.4	30.3	30.6
*DO (mg l^{-1})	7.3	6.6	7.0	6.8	7.7	8.3	8.0	4.3	5.8	8.8	7.7	5.5	10.8	5.7	5.1	5.1	6.9
*DO (mg l^{-1}) dawn	---	---	---	---	2.9	2.1	1.4	0.8	1.0	1.6	1.5	1.1	1.2	1.5	1.0	1.3	0.8
*pH	8.0	7.8	8.4	7.8	6.0	6.8	6.7	---	6.8	7.6	7.4	4.7	---	---	---	7.6	---
*Alkalinity (mg l^{-1})	76.0	58.2	85.0	62.7	49.2	62.7	53.7	62.7	53.7	40.3	49.2	58.2	53.7	58.2	49.2	49.2	44.8
*TKN (mg l^{-1})	1.3	5.7	2.8	4.2	1.5	3.8	4.9	7.8	3.2	5.2	5.8	3.8	6.7	5.6	5.8	6.5	2.0
*NH_4 (mg l^{-1})	0.5	1.9	1.8	4.0	1.8	0.4	0.6	0.9	0.8	0.6	0.8	0.5	0.6	0.5	0.6	0.3	0.3
NO_2 (mg l^{-1})	2.5	2.5	2.5	2.5	2.5	1.8	2.6	3.5	3.0	2.3	4.3	1.0	4.3	1.3	2.3	0.6	1.0
NO_3 (mg l^{-1})	40.0	40.0	40.0	38.8	21.3	21.3	30.0	43.8	52.5	52.5	37.5	25.0	43.8	36.3	33.8	11.3	25.0
*TP (mg l^{-1})	0.9	1.2	0.8	1.2	1.9	2.3	1.7	2.3	1.7	1.5	2.3	3.1	2.8	3.5	2.8	3.5	0.8
Chlophyl a($\mu g\ l^{-1}$)	46.0	34.3	35.9	40.9	61.1	37.4	22.3	63.1	30.7	51.6	56.3	24.0	28.2	35.4	25.8	13.6	10.0
SDD (cm)	42.5	26.3	23.3	22.8	21.3	15.8	21.8	21.8	24.5	26.5	24.8	18.3	26.3	17.3	23.8	25.5	19.0

Parameters marked with an asterisk (*) had significant differences among the time periods.

N= number of ponds

T= treatment

SDD= Secchi disk depth (visibility)

Table 5. *Mean values (n=4) of water quality parameters in feed treatment (T_2) weekly measured at 1400 h (except DO at dawn) during the culture period.*

Parameters	**Culture Week**																
T_2 (N=4)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
*Temperature(°C)	29.5	28.8	30.8	30.6	33.0	31.8	31.7	31.8	32.5	34.3	33.6	31.2	33.1	31.0	31.0	30.7	31.5
*DO (mg l^{-1})	5.9	5.3	5.5	5.6	5.7	5.6	6.1	5.3	4.7	6.8	6.1	5.1	6.4	6.7	3.7	3.9	6.3
*DO (mg l^{-1}) dawn	---	---	---	---	2.6	2.0	2.0	1.2	1.5	1.2	1.3	1.1	1.4	1.9	0.9	0.9	1.1
*pH	7.0	7.0	7.4	6.8	6.3	7.1	6.8	---	6.4	6.5	6.8	4.8	---	---	---	7.4	---
*Alkalinity (mg l^{-1})	67.1	62.7	80.6	53.7	71.6	62.7	67.1	58.2	58.2	58.2	67.1	53.7	49.2	40.3	44.8	40.3	44.8
*TKN (mg l^{-1})	0.8	1.5	0.5	0.5	0.5	1.4	0.7	0.9	0.4	0.5	1.5	3.6	2.4	3.0	2.2	3.2	1.0
NH_4 (mg l^{-1})	0.3	0.4	0.4	0.0	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
NO_2 (mg l^{-1})	0.0	0.0	0.0	0.0	1.3	1.3	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
*NO_3 (mg l^{-1})	0.0	0.0	0.0	5.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	1.3	0.0	1.3	0.0	0.0	0.0
*TP (mg l^{-1})	0.5	0.4	0.4	0.2	0.5	0.9	0.5	0.3	0.2	0.2	0.5	1.2	0.8	0.7	0.5	0.6	0.5
*Chlophyl a(µg l^{-1})	11.3	16.9	13.9	10.2	12.8	8.9	5.9	10.4	11.0	76.5	36.0	13.2	19.8	57.3	22.4	19.8	9.9
SDD (cm)	45.0	26.3	25.5	26.3	27.3	28.0	28.8	22.0	31.3	27.8	24.5	25.3	22.3	24.5	25.5	25.6	24.0

Parameters marked with an asterisk (*) had significant differences among the time periods.

N= number of ponds

T= treatment

SDD= Secchi disk depth (visibility)

Table 6. *Mean values (n=4) of water quality parameters in fertilizer plus feed treatment (T_3) weekly measured at 1400 h (except DO at dawn) during the culture period.*

Parameters	**Culture Week**																
T_3 (n=4)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
*Temperature(°C)	29.3	29.0	31.0	30.5	32.5	31.0	30.5	31.8	31.8	33.8	32.7	30.9	32.8	30.7	30.8	30.5	31.4
*DO (mg l^{-1})	7.6	8.0	7.8	8.4	8.5	7.6	10.9	7.1	9.6	9.0	12.2	6.7	8.9	6.8	4.0	4.2	7.6
*DO (mg l^{-1}) dawn	---	---	---	---	2.6	2.5	2.5	1.0	2.4	1.1	2.2	1.3	1.6	1.5	1.0	1.2	1.9
*pH	8.0	7.8	8.0	8.0	7.1	7.2	7.2	---	7.1	7.3	7.7	5.8	---	---	---	7.2	---
*Alkalinity (mg l^{-1})	85.0	58.2	71.6	71.6	62.7	44.8	58.2	58.7	49.2	44.8	49.2	53.7	49.2	49.2	49.2	44.8	44.8
*TKN (mg l^{-1})	0.9	2.9	1.5	0.8	1.3	4.6	5.3	8.0	2.2	3.8	3.4	4.3	9.3	6.1	6.7	5.8	2.8
NH_4 (mg l^{-1})	0.4	0.8	0.4	2.0	3.0	1.9	1.4	1.3	1.9	1.1	0.6	2.1	0.5	0.6	0.5	0.4	0.8
*NO_2 (mg l^{-1})	0.0	0.1	0.0	0.3	0.0	1.0	0.5	2.6	1.8	1.8	3.0	1.8	1.3	2.8	2.8	0.1	1.1
*NO_3 (mg l^{-1})	5.0	5.0	3.8	3.8	6.3	7.5	15.0	40.0	30.0	21.3	27.5	62.5	27.5	33.8	31.3	13.8	27.5
*TP (mg l^{-1})	0.9	1.1	0.7	0.8	1.3	1.9	0.9	1.0	0.8	0.9	0.6	2.5	0.9	1.6	0.9	3.9	2.0
Chlophyl a(µgl^{-1})	57.4	36.4	30.6	44.4	44.6	64.6	48.5	115.4	43.4	23.6	86.3	28.1	39.8	44.3	43.0	19.7	12.1
*SDD (cm)	43.5	32.0	19.5	23.0	18.0	16.3	20.0	13.3	22.5	16.0	21.5	19.5	17.5	21.0	25.5	24.0	26.8

Parameters marked with an asterisk (*) had significant differences among the time periods.

N= number of ponds

T= treatment

SDD= Secchi disk depth (visibility)

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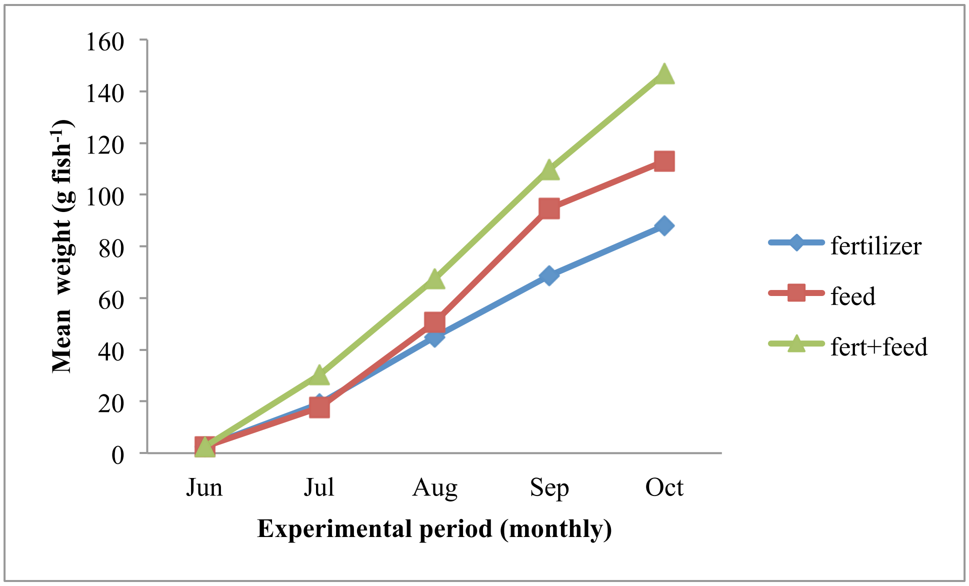

Figure 1. *Changes in mean weight (growth) of tilapia during culture under three treatments.*

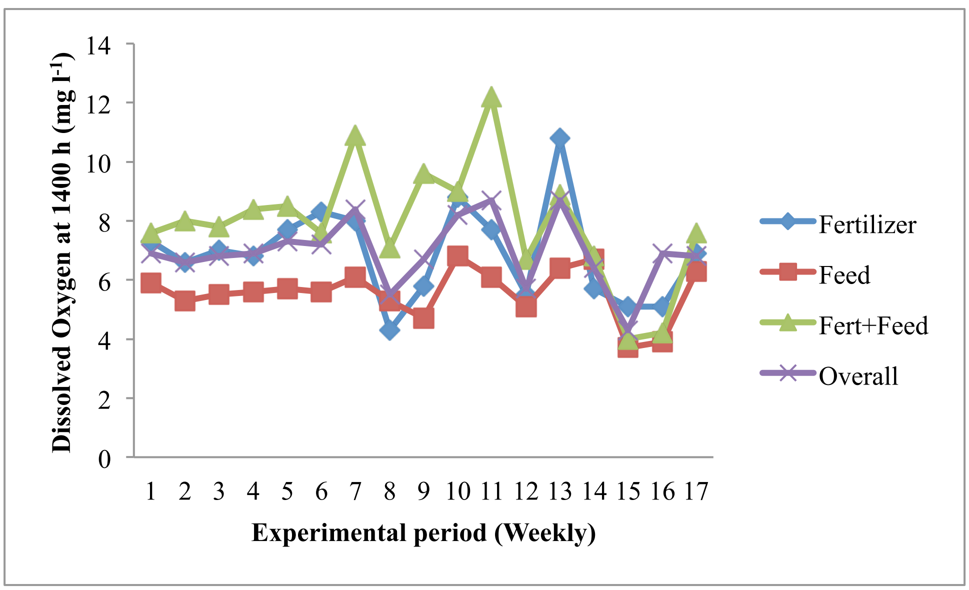

Figure 2. *Changes in dissolved oxygen content of pond water at 1400 h during culture in eacl*

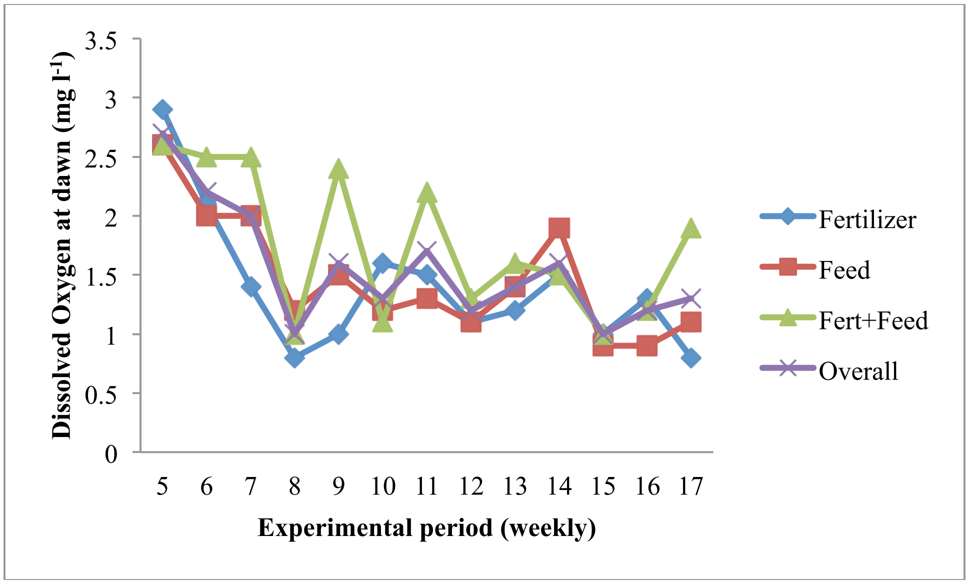

Figure 3. *Changes in dissolved oxygen content of pond water at dawn during culture in each treatment.*

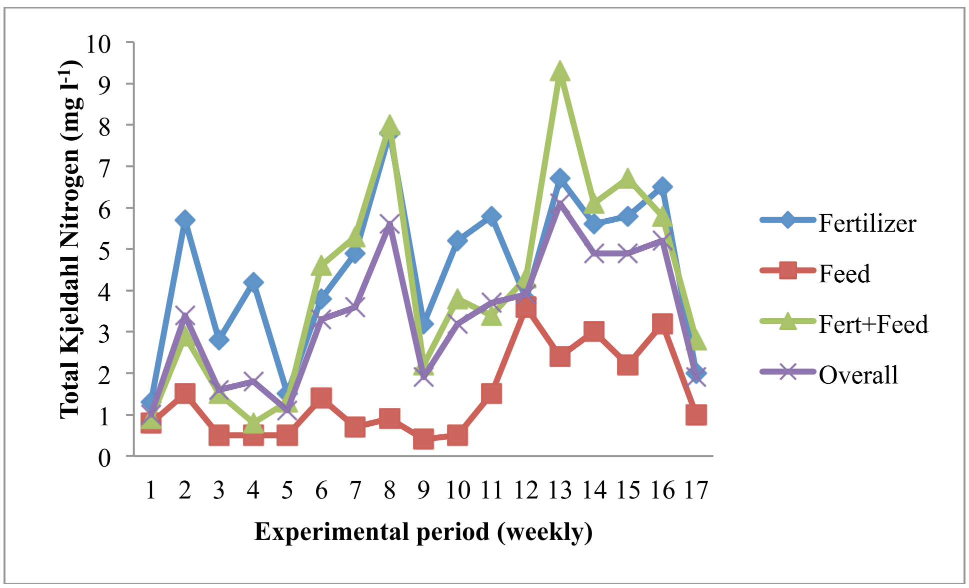

Figure 4. *Changes in total Kjeldahl nitrogen during culture in each treatment.*

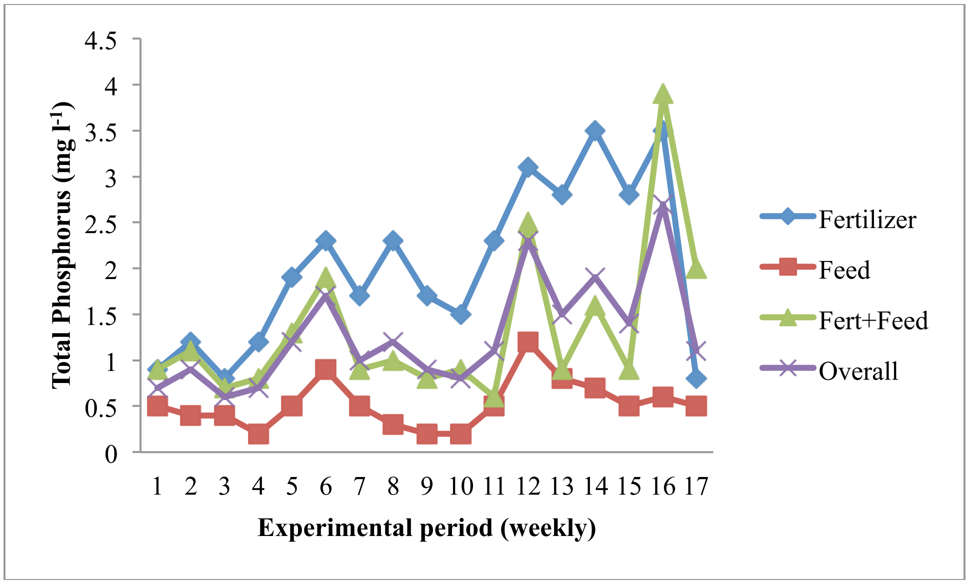

Figure 5. *Changes in total phosphorus during culture in each treatment*

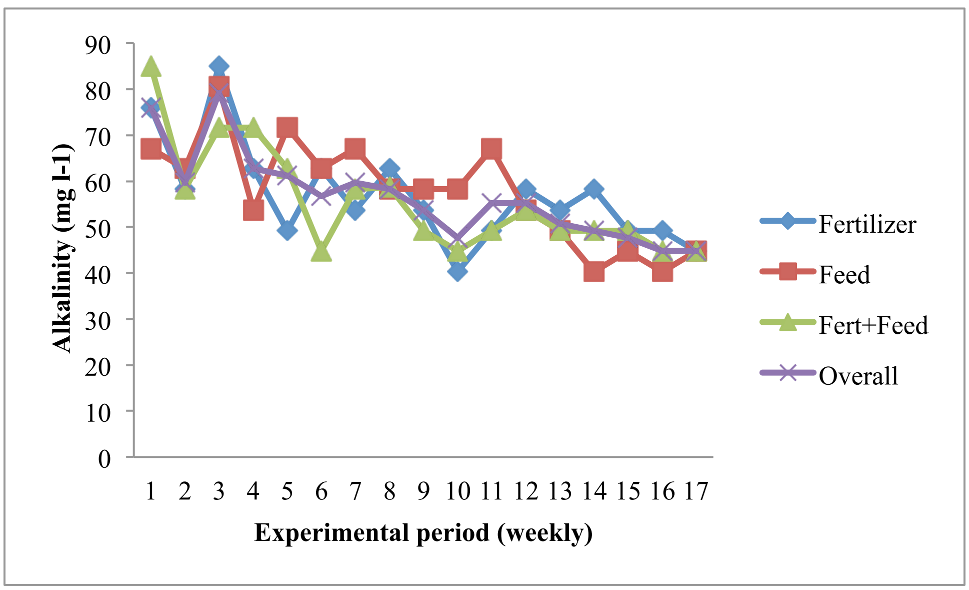

Figure 6. *Changes in alkalinity during culture in each treatment.*

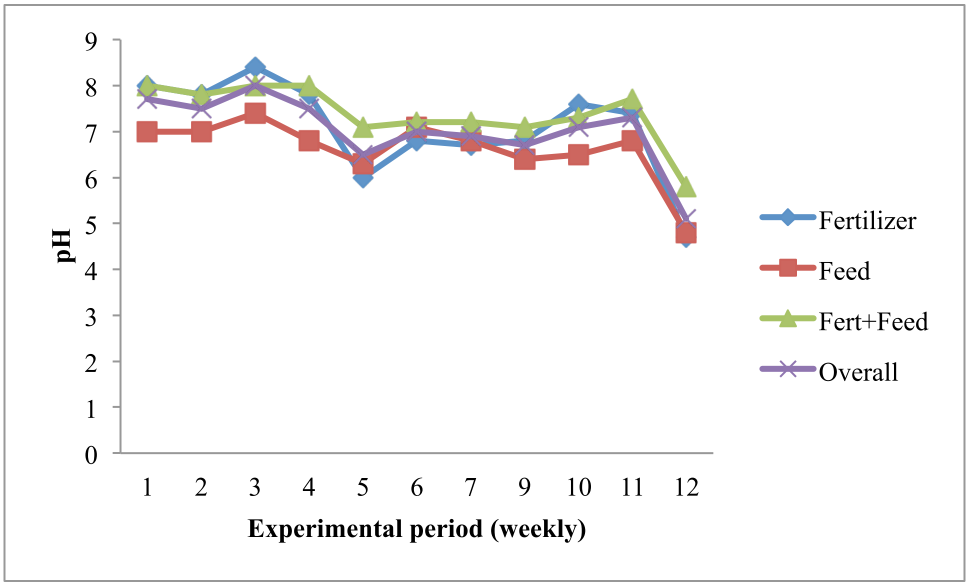

Figure 7. *Changes in pH during culture in each treatment.*

1. Pond preparation (drying)

2. Liming (agricultural lime $CaCO_3$)

3. Fertilization (suspending in a porous bag in the middle of the pond) using Urea and DAP

4. Measuring water qualities (DO, pH and temperature) using DO/pH meter

5. Water sampling and measuring (water quality) using Test-kits

6. **Feeding**

7. Measuring evaporation (evaporation pan)

8. Experimental pond-site

TOPIC AREA:
EXPERIMENTAL POND UNIT ASSESSMENT

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EXPERIMENTAL POND UNIT ASSESSMENT IN NICARAGUA

Production System Design & Best Management Alternatives/Study/09BMA13UH

FINAL INVESTIGATION REPORT
Printed as submitted in Spanish

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RESUMEN

La caracterización de estanques de cultivo de tilapia *Oreochromis niloticus*, se realizó en la Granja Escuela Piscícola La Polvosa, ubicada en el municipio de Materare, departamento de Managua, Nicaragua. Se utilizó una línea de tilapia gift genéticamente mejorada, cultivada en 180 días en tres estanques de 600 m^2. Se realizaron mediciones diarias de parámetros físico-químicos *in situ*, muestreos quincenales de calidad de agua físico-químico, microbiológico (pH, oxígeno disuelto, temperatura, alcalinidad, nitrito, nitrato, fósforo reactivo soluble, nitrógeno amoniacal total, nitrógeno amoniacal no ionizable, clorofila a, sólidos suspendidos totales, sólidos disueltos totales; *Escherichia coli*, coliformes totales, coliformes fecales, Enterococcus, Pseudomonas y Aeromonas, y controles biométricos cada quince (talla, peso y factor de conversión alimenticio) con el objetivo de identificar si en condiciones de cero recambio de agua, se provoca estratificación o alteración de la calidad del agua (física, química y microbiológica) que pudiera interfieren en los rendimientos técnicos del cultivo y la calidad del producto. Las pérdidas del nivel de operación del estanque y las bajas concentraciones de oxígeno disuelto, hicieron necesaria la incorporación de agua, aunque esta fue poco frecuente en porcentajes bajos. Los indicadores técnicos de cultivo fueron similares a los publicados como óptimos por otros autores. No se encontró diferencias significativas en los parámetros físico-químicos y microbiológicos del agua entre los estanques, por tanto no se considera que la calidad del agua haya influido en los indicadores técnicos de cultivo. Se encontró estratificación, la cual estuvo influenciada los rayos solares ya que se observó que a partir que disminuía la intensidad del sol los estratos desaparecían.

INTRODUCCIÓN

El pescado es una importante fuente de proteínas, especialmente cuando otras fuentes de proteínas de animales son escasas o costosas. FAO 2002, indica que el pescado proporciona alrededor del 19 por ciento del aporte proteínico en los países en desarrollo. Existen varias especies de tilapia que se cultivan en el mundo. Este grupo de peces está creciendo en importancia, tanto como especie para el consumo interno, como para exportación. En el año 2000 su producción global fue de 1.5 millones de toneladas métricas muy superior a la producción obtenida en 1970 que fue de 28,260 toneladas métricas (FAO, 2004).

Las tilapias son fáciles de cultivar porque no son comúnmente afectadas por enfermedades y problemas de calidad del agua; también porque son especies que crecen muy rápido bajo condiciones de hacinamiento y se puede obtener altos niveles de producción. Sin embargo, el manejo de los estanques es un factor clave, donde un error técnico puede reducir el rendimiento o provocar la muerte de la totalidad o parte de los peces en un estanque.

La calidad del agua en los estanques es un factor determinante de la producción de peces. Esta calidad, estará fuertemente influenciada por las prácticas del manejo realizado en los estanques; donde se incluye, por ejemplo, la densidad de siembra, las estrategias adoptadas para su fertilización, la alimentación suplementaria ofrecida, la toma de datos sobre las variables ambientales y químicas, etc. (Egna, H. & Boyd, C. 1997).

En Nicaragua desde el año 1999 se han venido haciendo esfuerzos por cultivar tilapias, principalmente en comunidades del norte del país (Estelí, Nueva Segovia y Matagalpa). En año 2001 se inició el cultivo en jaulas flotantes en el Lago Cocibolca de Nicaragua, sin embargo, este fue descontinuado en el año 2009. Actualmente, en el marco del Programa de Acuicultura de Pequeña Escala y Recursos Limitados (APERL) del Gobierno de Reconciliación y Unidad Nacional se han retomado los esfuerzos por fomentar el cultivo como una medida de generación de proteínas e ingresos a familias campesinas, encontrándose actualmente la actividad en niveles incipientes.
Es importante señalar que el hecho de ser una actividad de poco desarrollo en el país hace que la oferta de insumos de producción y de equipamiento sean limitados y de alto costo, y por otro lado los bajos precios de compra del producto cosechado, por parte de las plantas procesadoras, hace que la producción de tilapia se vuelva una actividad no rentable, principalmente al pequeño productor. Por lo cual es necesario identificar técnicas de manejo de los estanque de producción de tilapia que permitan bajar los costos de producción, sin que estos afecten los rendimientos productivos.

En este sentido el estudio de "Caracterizar los estanques de cultivo de tilapia *Oreochromis niloticus (*gift) en condiciones de cero recambio de agua, pretende generar información de manejo basado en la premisa de disminuir costos de producción incurridos en el continuo bombeo para recambio de agua. Para ello se establecieron las siguientes hipótesis:

- El cero recambio de agua no altera los parámetros físico-químicos del agua que interfieren en los rendimientos técnicos del cultivo de tilapias.
- El cero recambio de agua no provoca estratificación de la columna de agua en las condiciones de temperatura, oxígeno disuelto y pH que puedan influir en el cultivo.
- Los niveles bacterianos alcanzados en los estaques no afectan el cultivo y se mantienen en los límites permisibles según las normas de inocuidad para la comercialización del producto.
-

MATERIALES Y MÉTODOS

Ubicación del sitio de estudio: El estudio se llevó a cabo en la Granja Escuela Piscícola La Polvosa, ubicada en el km 22 ½ de la carretera nueva a León en el municipio de Mateare, departamento de Managua. El clima del municipio es cálido, caracterizado como tropical de sabana, con una marcada estación seca de cuatro a seis meses de duración, confinada principalmente entre los meses de noviembre a abril de cada año. La temperatura promedio se encuentra entre los 28 y 28.5 °C en los meses frescos. La precipitación varía entre los 1,000 y 1,200 mm y una altitud sobre el nivel del mar de 50 metros (INIFOM. s.f).

Diseño experimental: La investigación se realizó en tres estanques (denominados E-1, E-3 y E-4) de 600 m^2 (20 m x 30 m) con profundidad promedio de 1.2 m forrados con geomembranas (ver figura No.1). Se sembró a una densidad de dos alevines/m^2 (3,600 alevines) con peso promedio de 2.18 gramos de una línea genéticamente mejorada de tilapias gift *Oreochromis niloticus* previamente revertidos con hormona 17 alfa-metil testosterona, provenientes de la Empresa Central American Fish. Se utilizó agua de pozo bombeada al reservorio y distribuida por gravedad a los estanques.

Cada estanque contó con muelles flotantes para facilitar la toma de datos y muestras, así como con estadias ubicadas en las cuatro esquinas y el centro. Los estanques previamente fueron acondicionados y durante el cultivo se mantuvieron los alrededores libres de malezas.

Manejo del cultivo: Los alevines fueron transportados por dos horas en tanque provisto de oxígeno. Se realizó climatización por gradiente de temperatura durante dos horas bajando 1 °C por cada 15 minutos. El tiempo de experimentación fue de 180 días, iniciando el 19 de noviembre del año 2012 y finalizó el 20 de mayo del año 2013.

De acuerdo a Otárola (2002) el modelo de producción utilizado fue el sistema de cultivo semi – intensivo donde se maneja una combinación de alimento natural y un suplemento de alimento concentrado con densidades uno y dos peces por m^2.

Figura No.1. *Plano de ubicación de estanques de estudio en Granja Escuela Piscícola La Polvosa*

Se utilizó alimento concentrado con 38 % de proteína cruda durante los primeros 65 días a partir de esta fecha se alimentó con concentrado al 28 % de proteína cruda, suministrado en dos raciones (8.00 a.m. el 60% y a las 3:00 p.m. el 40%). Para ajustar la ración diaria se tomo como referencias la tabla de alimentación para cultivo en tres etapas de PRADEPESCA, el consumo diario de alimento y las concentraciones de oxígeno disuelto en el agua. Es así que a partir de los trece días de cultivo la ración alimenticia fue variando en función de la observación del consumo de alimento, llegando a disminuir hasta un 15 % o incrementar hasta 20 % la ración en condiciones normales. Igualmente en periodos de baja concentración de oxígenos por la mañana se disminuyó la ración diaria de alimento entre un 30% hasta un 100%.

Manejo del volumen de agua: El llenado de los tres estanques inició siete días antes de la siembra. El E-1 alcanzó su máximo nivel de 660 m^3 a los dos días, el E-3 alcanzó los 660 m^3 a los cuatro días y el E-4 con 630 m^3 alcanzó su nivel máximo a los siete. El cultivo se mantuvo bajo la premisa de cero recambios de agua, sin embargo fue necesario adicionar agua a partir del día 72 de cultivo para recuperar el nivel de la columna de agua, ya que ha esta fecha se había perdido el 23.6 % del volumen del agua en el E-1, el 14.55 % en el E-3 y 20 % en el E-4. Adicionalmente fue necesario subir y bajar nivel de agua en doce ocasiones para controlar la alta población de fitoplancton que provocó alta variabilidad del oxígeno disuelto.

A los diecisiete días de cultivo, se aplicó una única dosis de seis libras de fertilizante NPK 18-46-0. De estas cuatro fueron diluidas en cinco galones de agua por dos horas y aplicados de una vez en el estanque y las restante dos libras se colocaron en saco macen en la entrada del agua durante una semana hasta su dilución total.

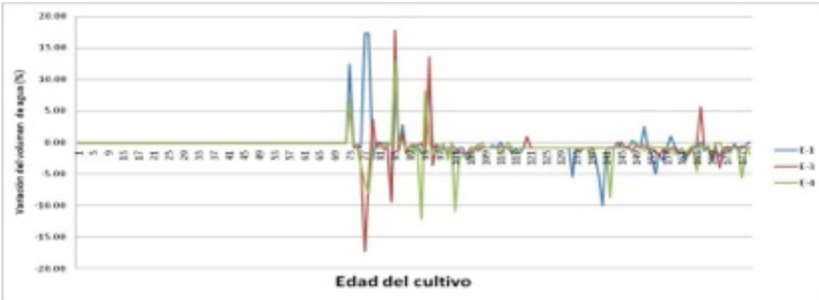

Fig. No.2. *Variación del volumen de agua (%). Los picos positivos representan adición y los negativos extracción de agua.*

Control biométrico del cultivo: Se determinó peso y talla cada catorce días a cien individuos capturados con chinchorros (luz de malla de ½ y ¼ de pulgada), cada uno fue pesado en balanza gramera de precisión marca Kern con capacidad de 4000 g. Con los resultados de crecimiento se estimó el factor de conversión alimenticio ($FCA= A/(B_f-B_i)$), la tasa de crecimiento real ($TCR= (P_f-P_i)/d)$), biomasa ($B=Pp*N/1000$). La mortalidad se calculó con la cantidad total de individuos sembrados, menos el número total de individuos cosechados ($M= Ni-Nf$).

Análisis físico-químico de agua: Se realizó mediciones en tres estratos (superficie, medio y fondo) en dos momentos del día (6 a.m. y 6 p.m.) durante el cultivo de las variables de oxígeno disuelto, temperatura, pH, alcalinidad y trasparencia (medio día). Semanalmente se tomaron muestras de la columna de agua (6 a.m.) para realizar análisis de alcalinidad, clorofila *a*, fósforo reactivo soluble, fósforo total, nitrato, nitrito, nitrógeno amoniacal total, nitrógeno amoniacal no ionizado, sólidos disueltos totales, sólidos suspendidos totales.

Estratificación de la columna de agua: Se realizó mediciones de oxígeno disuelto, temperatura y pH cada diez centímetros de profundidad de la columna de agua, durante doce horas iniciando a las 6 a.m. y finalizó a las 6 p.m. el cual fue realizado en tres momentos del cultivo: un día antes de la siembra (0 días), a los 90 y 180 días de cultivo. Para determinar si existe o no estratificación se realizó la prueba de diferencia mínimas significativas donde H_o**:** $|\hat{Y}_i- \hat{Y}_j|$ sean iguales, contra la alternativa de H_1 : $|\hat{Y}_i- \hat{Y}_j|$ sean diferentes.

Análisis bacteriológicos en agua y tejido: Mensualmente se tomó muestra de la columna de agua (6 a.m.) para realizar análisis de *Escherichia coli*, coliformes totales, coliformes fecales, Enterococcus y Pseudomonas. También se realizó muestreo de peces (5 peces/estanque/3 muestreos) a los 0, 90 y 180 días del cultivo para análisis de E. coli, coliformes totales, coliformes fecales, Pseudomonas y Enterococcus en tejido externo y bacterias *Aeromonas spp, Pseudomonas spp* y Enterococcus fecales en órganos internos.

Todas las muestras fueron custodiadas y analizadas según los procedimientos de trabajo del Laboratorio Ambiental del Instituto de Capacitación, Investigación y Desarrollo Ambiental de la Universidad Centroamericana (Instituto CIDEA-UCA).

Análisis de datos: Se utilizó los paquetes estadísticos SPSS 20, STATISTICA 7, y Microsoft Excel 2010. Se aplicó ANOVA de un factor, homogeneidad de varianza, prueba Post Hoc de comparación múltiple, correlaciones y parámetros descriptivos.

RESULTADOS

3.1 INDICADORES TÉCNICOS DE CULTIVO

Crecimiento: Los tres estanques en cultivos sembrados a 2 peces/m^2 alcanzaron un crecimiento promedio en peso de 517.74 g en 180 día de cultivo, lo cual representó un incremento diario de 2.88 g. El análisis estadístico indica únicamente diferencias significativas ($P<0.05$) del E-1 con el E-3 y el E-4, siendo el E-1 el que alcanzó el mejor crecimiento de 602.16 ± 6.96 g de peso promedio final, con un crecimiento diario de 3.35g.

Según la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO) tilapias macho cultivadas con alimentos balanceados de alta calidad (35 % de proteína) a densidades de 1 y 3 peces/m^2, alcanzan un peso de entre 400 y 500 g en un período de 5 a 8 meses, por otro lado Otárola (2002) obtuvo pesos de cosecha de 545 g en 235 días con sistema de cultivo en tres fases y Rakocy (2011) en sistema de cultivo con biofloc obtuvo pesos de cosecha de 912 g en 175 días; 67 g 201 días, 707 g 182 días y 745 g 180 días. Como podemos ver los resultados obtenidos en esta investigación, se encuentra entre los rangos mencionados. Ver tabla No.1.

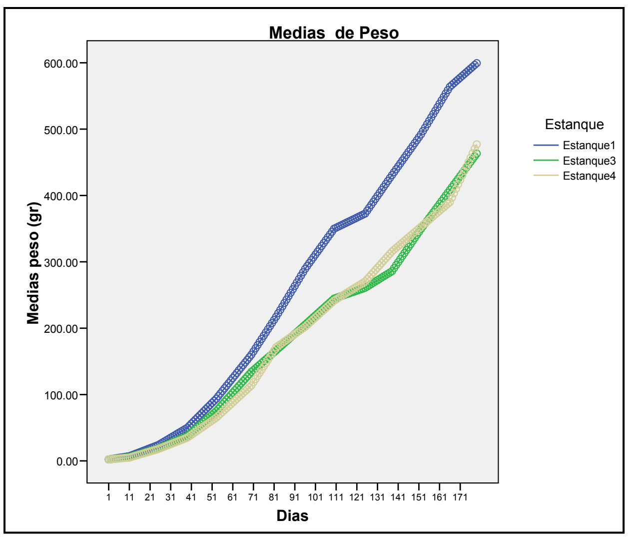

Fig. No.3. *Comportamiento del crecimiento (peso) de la tilapias gift Oreochromis niloticus*

En Fig. No.4 se presenta la relación existente entre el peso y la longitud en los tres estanques, donde ambas variables se comportaron de manera similar, con una menor dispersión en las primeras etapas del cultivo la cual fue aumentando a medida que la tilapia crecía.

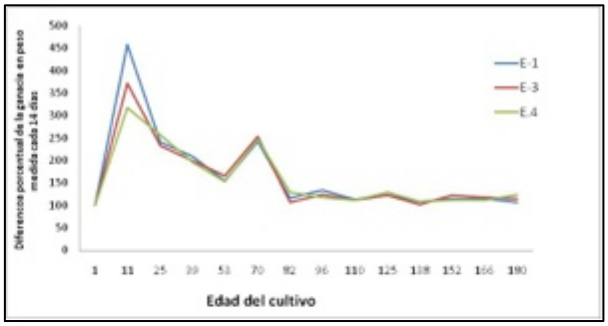

Fig. No.4. Dispersión de peso y longitud de la tilapia en cultivo en los tres estanques

En términos porcentuales las mayor ganancia en peso se dió en los primeros ochenta día de cultivo, llegando a alcanzar hasta un 450 % de incremento del peso entre una y otra medición realizada cada catorce días, donde el E-1 a los 11 día de cultivo experimentó un mayor porcentaje de crecimiento con respecto a los otros dos estanques.

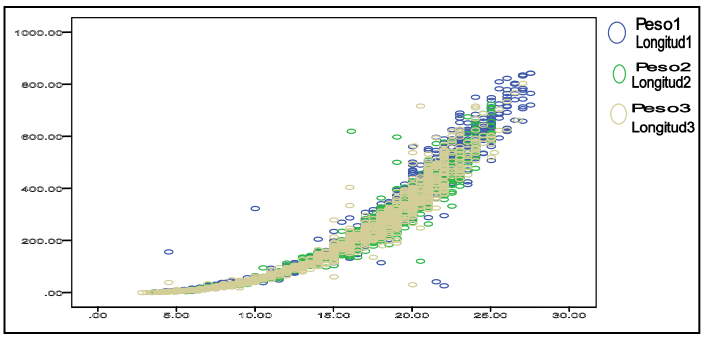

***Fig. No.5**. Porcentaje de crecimiento gana entre cada periodo de muestreo realizadao cada catorce días*

Sobrevivencia: En promedio se obtuvo una sobrevivencia de 70.4 %, donde el E-1 registró la mayor sobrevivencia (75.25 %) seguido del E-3 con 72.25 %, lo cual representó un rendimiento productivo promedio de 7.3 tonelada por hectáreas. Según FAO los rendimientos normales de cultivo de tilapia varían de 6 a 8 toneladas/ha/ciclo de cultivo, pero se han registrado rendimientos tan altos como 10 toneladas/ha/ciclo en el noreste de Brasil, donde son ideales el clima y la calidad del agua. En sistemas de cultivo de mayor control como el Biofloc Rakocy (2011) registró sobrevivencia de 78.9 %, 81 %, 86 y 99.7 %.

Factor de conversión alimenticia (FCA): En promedio se obtuvo 1.56 de FCA, siendo el E-1 el que alcanzó el mejor indicador con 1.51 seguido del E-3 con 1.55 y el E-4 que fue de 1.61, encontrándose diferencias significativas únicamente entre el E-1 con E-4. Según Paul M. Baltazar & Alfredo R. Palomino (2004) indican que es posible obtener FCA de 1:0.8 y 1:1.5.

***Tabla No. 1**.Resultado de indicadores técnicos del cultivo de tilapia gift* *Oreochromis niloticus*

Indicador técnico	Estanque No.1	Estanque No.3	Estanque No.4	Promedio
Peso inicial (gr)	2.18	2.18	2.18	2.18
Peso final (gr)	602.16±6.96	467.35±6.96	483.70±6.96	517.74
Crecimiento diario	3.35	2.60	2.69	2.88
Sobrevivencia %	75.25	72.75	63.25	70.4
Factor de conversión alimenticia	1.51	1.55	1.61	1.56

Como se puede observar el E-1 reportó los mejores indicadores técnicos del cultivo, es decir mayor crecimiento, mayor sobrevivencia y un mejor indicador de conversión alimenticia, esto puede estar asociado a que es el estanque que tuvo mayor tiempo de maduración del agua, mejor eficiencia en el flujo del agua y el que se encuentra más próximo a la casa de técnico, lo cual disminuye el potencial ataque de aves.

3.2 CARACTERÍSTICAS FÍSICO-QUÍMICA DEL AGUA DE CULTIVO

Oxígeno disuelto: El oxígeno disuelto juega el papel más importante en la calidad biótica de las agua de cría; es indispensable para la respiración de los organismos y facilita la degradación de la materia orgánica detrítica y la realización de los procesos bioquímicos (ALZIEU Claude. S.f), el éxito de un operador de una granja depende seriamente del entendimiento de los factores que afectan su concentración (Páez Ozuna. S,f). Según Boyd (1998) rangos de 5 a 15 mg/l de oxígeno disuelto son los recomendados para cultivos acuáticos, fuera de éstas condiciones el pez se expone a estados de anoxia y sobresaturación de oxígeno. El efecto en la tilapia depende de la concentración y grado de exposición, según NICOVITA (s.f) concentraciones de 0.0 a 0.3 mg/l los peces pequeños sobreviven en periodos cortos, de 0.3 a 2.0 mg/l es letal a exposiciones prolongadas, de 3 a 4 mg/l los peces sobreviven pero crecen lento, siendo el rango deseable para el crecimiento del pez mayor de 4.5 mg/l.

En la investigación, a partir del día 44 de cultivo, los tres estanques en los tres estratos, presentaron concentraciones menores de 5 mg/l de oxígeno disuelto en horas de la mañana manteniéndose así hasta los 70 día de cultivo, fecha a partir de la cual se incorporó agua, por un periodo de 30 días, registrándose en este momento en el E-1 y E-4 la mayor irregularidad en la concentración de oxígeno disuelto, por la mañana vario entre 0.01mg/l mínimo a 11.2mg/l máximo y por la tarde entre 2.91 mg/l mínimo hasta 24.8mg/l máximo. Logrando estabilizar la variabilidad del oxígeno hasta los 129 días de cultivo, sin embargo este fue decreciente paulatinamente hasta ser necesaria la incorporación de agua hacia finales del cultivo, aunque en este momento en menor porcentaje de adición.

Tabla No.2. *Concentraciones máximas, mínimas y promedio de oxígeno disuelto (mg/l) registrados por estrato en cada estanque de cultivo de tilapias gift Oreochromis niloticus*

Oxígeno disuelto (mg/l)	Estaque No.1						Estanque No.3						Estanque No.4					
	Superficie		Medio		Fondo		Superficie		Medio		Fondo		Superficie		Medio		Fondo	
	a.m.	p.m.	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m
Valor mínimo	0.08	6.79	0.02	6.62	0.02	4.38	0.08	6.12	0.02	6.06	0.02	3.01	0.04	3.18	0.02	3.03	0.01	2.91
Valor máximo	11.2	19.2	10.5	18.3	10.5	18.4	10.8	21.6	10.7	21.1	10.8	24.8	10.9	20.3	10.9	20.7	10.8	19.5
Promedio	4.3	12.3	4.1	12.1	4.1	11.5	4.7	11.8	4.5	11.6	4.5	10.7	4.3	11.7	4.1	11.5	4.1	10.9

Como se puede observar en la Fig. No5, por la mañana no se observa grandes diferencia entre los estratos, sin embargo por la tarde si es evidenció algunos momentos de menor concentración de oxígeno disuelto en el estrato de fondo con respecto a los otros dos estratos. Por otro lado encontramos que a partir del día 51 de edad del cultivo la concentraciones de oxígeno disueltos de la mañana se encuentran fuera de los rangos recomendados para cultivo de tilapia. No se observó diferencia significativa en el comportamiento del oxígeno entre los estanques.

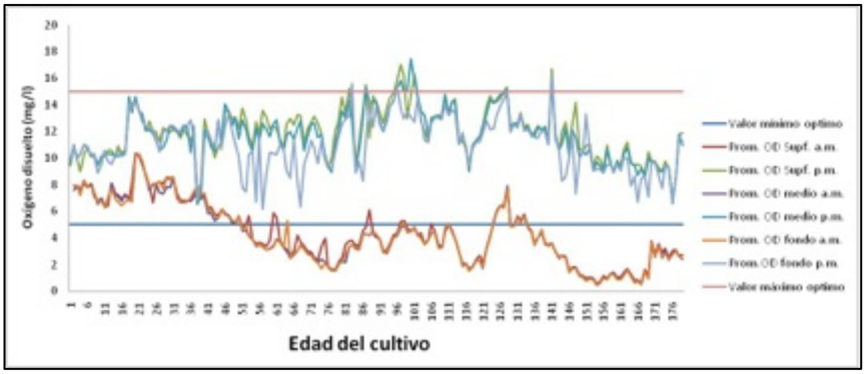

Fig. No.6. Comportamiento del oxígeno disuelto (mg/l) en el estrato superficial, medio y fondo del promedio de los tres estanques de cultivo de tilapias gift Oreochromis niloticus.

Temperatura: La temperatura es uno de los factores ambientales más importantes para todos los organismos acuáticos: influye en la oxigenación de las agua, en la reproducción primaria y el crecimiento de las especies (ALZIEU Claude. S.f), según NICOVITA (s.f), el rango óptimo de temperatura para el cultivo de tilapias fluctúa entre 28 °C y 32 °C, aunque ésta puede continuarse con una variación de hasta 5 °C por debajo de este rango óptimo. Los cambios de temperatura afectan directamente la tasa metabólica, mientras mayor sea la temperatura, mayor tasa metabólica y, por ende, mayor consumo de oxígeno.

En promedio la temperatura se mantuvo entre los 26.8 °C a 29.6 °C, con temperaturas mínimas de 22.51 °C y máximas 32.9 °C registradas ambas en el estrato de fondo. A excepción del día uno de cultivo que registro alta temperatura, fue el mes de marzo donde se dio la mayor variación temperatura, presentando los más bajos valores de temperatura al inicio del mes y los más altos al finalizar éste, periodo que concedió con variaciones similares de temperatura atmosférica.

***Tabla No.3**. Niveles máximos, mínimos y promedio de temperatura (°C) registrados por estrato en cada estanque de cultivo de tilapias gift Oreochromis niloticus*

Temperatura (°C)	Estaque No.1						Estanque No.3						Estanque No.4					
	Superficie		Medio		Fondo		Superficie		Medio		Fondo		Superficie		Medio		Fondo	
	a.m.	p.m.	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m
Valor mínimo	22.91	24.62	22.94	25.79	22.51	25.77	23.09	25.68	23.12	25.68	23.10	25.78	23.39	25.89	23.38	25.90	23.36	25.73
Valor máximo	30.2	32.6	30.2	32.6	31	32.6	29.9	32.5	30.0	32.5	30.0	32.3	29.9	32.2	29.9	32.2	29.9	32.9
Promedio	27	29.5	27	29.6	27	29.3	26.8	29.2	26.8	29.3	26.8	29.0	26.8	29.3	26.8	29.3	26.8	29.2

Como se puede observar en la Fig. No.6, por la mañana no se observa grandes diferencia entre los tres estratos, sin embargo por la tarde si se evidenció algunos momentos de mayor temperatura en el estrato de medio. Al comparar este resultado con los datos de oxígeno disuelto encontramos una relación directamente proporcional con los momentos en que hubo mayor temperatura en el agua de los estanques y al igual que el oxígeno disuelto la temperatura medida en horas de la mañana se encontró fuera del rango recomendado para el cultivo de tilapia. Entre los estanques no se encontró diferencia en el comportamiento de la temperatura.

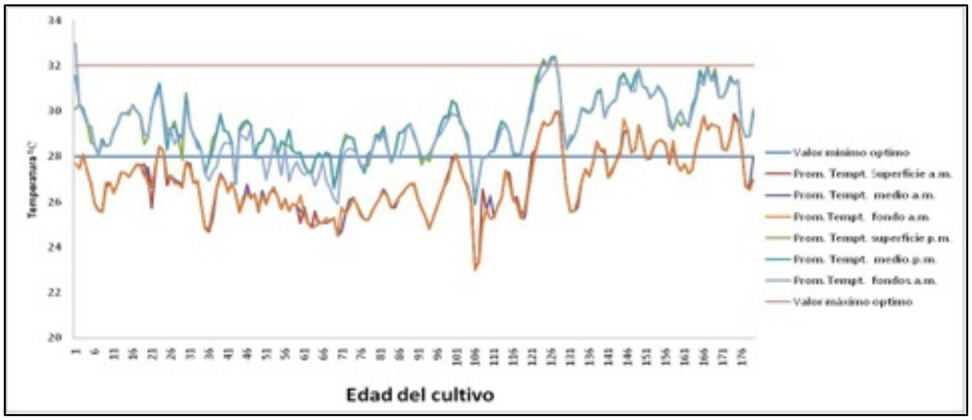

Fig. No.*7. Comportamiento de la temperatura (°C) en el estrato superficial, medio y fondo del promedio de los tres estanques de cultivo de tilapias gift Oreochromis niloticus.*

Alcalinidad y pH: Es una medida de todas las bases contenidas en el agua. La fuente de alcalinidad en el agua, se debe a las sales de ácidos débiles, que se disocian en el agua. Gran parte de la alcalinidad en el agua dulce, es consecuencia de los iones de carbón que está interrelacionados; dependiendo estas proporciones del pH existente en el medio. A medida que el pH aumenta, el bicarbonato se hace más común, hasta alcanzar un pH de 8.3. A menudo en estanques de cultivo el pH se encuentra entre 7 y 8 unidades. La alcalinidad puede limitar la productividad primaria cuando se encuentra en los 30 mg/l, mientras que en otro extremo, una alcalinidad de 120 mg/l puede reducir la productividad primaria sin fertilizar (Egna, H. & Boyd. C. 1997).

Para el cultivo de tilapia según NICOVITA (s.f), el rango óptimo de pH está entre 6.5 a 9.0 valores por encima o por debajo de estos rangos, causan cambios de comportamiento en los peces como letárgia, inapetencia, retardan el crecimiento y retrasan la reproducción. Valores de pH cercanos a 5 producen mortalidad en un período de 3 a 5 horas, por fallas respiratorias; además, causan pérdidas de pigmentación e incremento en la secreción de mucus de la piel. Cuando se presentan niveles de pH ácidos, el ion Fe^{++} se vuelve soluble afectando las células de los arcos branquiales y por ende, disminuyen los procesos de respiración, causando la muerte por anoxia. La alcalinidad está relacionada directamente con la dureza del agua, para el cultivo de tilapia debe tener una alcalinidad entre 100 ppm a 200 ppm.
Durante el estudio se registraron pH promedios entre los 8.6 a 9.5 con valores mínimos de 4.7 y 11 máximo, pero en general se presento un pH alcalino. La adición de fertilizante evidenció un efecto directo en el pH, tornándose éste a más básico, lo cual pudo deberse a un incremento de la productividad primaria que al hacer uso del CO_2 incidió en un incremento del pH. Posterior a ello se registró momentos donde bajo el pH con alta variación donde se registró datos de pH neutro, lo cual pudo deberse al incremento de materia orgánica en descomposición a efectos del blom de productividad primaria, que incrementó el CO_2 y consecuentemente disminuyó el pH, generándose alta variabilidad del pH entre los tres estratos, como se observa en la Fig. No.7.

Tabla No.4*. Niveles máximos, mínimos y promedio de pH registrados por estrato en cada estanque de cultivo de tilapias gift Oreochromis niloticus*

pH	Estaque No.1						Estanque No.3						Estanque No.4					
	Superficie		Medio		Fondo		Superficie		Medio		Fondo		Superficie		Medio		Fondo	
	a.m.	p.m.	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m
Valor mínimo	4.87	6.02	4.77	5.79	4.94	5.98	6.07	7.21	5.54	5.06	5.67	6.53	6.12	5.99	5.42	6.59	5.56	6.48
Valor máximo	10.6	11.1	10.5	11.0	10.4	10.6	10.6	10.9	10.4	11.0	10.5	10.3	10.83	10.90	10.84	10.68	10.93	10.45
Promedio	9.2	9.6	8.8	9.2	8.6	9.0	9.2	9.5	8.9	9.2	8.8	9.0	9.2	9.4	8.9	9.1	8.7	9.0

Durante los primeros cien días de edad del cultivo se mantuvo una diferencia del comportamiento del pH entre los tres estratos, siendo más alcalino en el estrato de superficie y menos alcalino el estrato del fondo. Al comparar los datos, se encontró que por la mañana el pH baja y sube por la tarde, lo cual coincide con lo indicado por NICOVITA (s.f) quien indica que el pH en el agua fluctúa en un ciclo diurno, principalmente influenciado por la concentración de CO_2, por la densidad del fitoplancton, la alcalinidad total y la dureza del agua. Según este mismo autor el pH para tilapia debe de ser neutro o muy cercano a él, con una dureza normalmente alta para proporcionar una segregación adecuada del mucus en la piel y cómo podemos observar en la gráfica únicamente al inicio y al final del cultivo éste se mantuvo dentro de los rangos sugeridos para al cultivo de tilapia. Los tres estanques experimentaron éste mismo comportamiento.

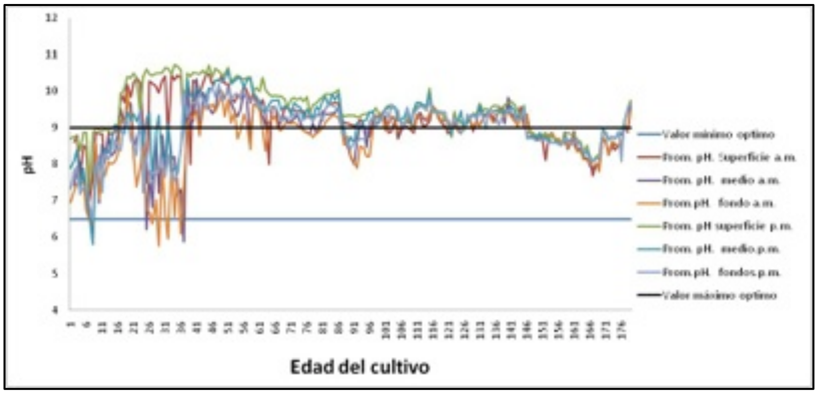

Fig. No.8. *Comportamiento del pH en el estrato superficial, medio y fondo del promedio de los tres estanques de cultivo de tilapias gift Oreochromis niloticus.*

La alcalinidad en promedio se mantuvo entre los 168.7 a 176.8 mg $CaCO_3$/l, con valores mínimos de 126 mg $CaCO_3$/l y máximas de 226 mg $CaCO_3$/l. En términos generales la alcalinidad tuvo poca fluctuación a excepción de un incremento que se dio durante la aplicación del fertilizante, con una marcada disminución del pH, donde posterior a ello la alcalinidad disminuyó, generando un efectos estabilizar lo cual puedo deberse al aumento del CO_2 disminuyó el pH y aumentó la concentración de bicarbonatos incrementándose así la alcalinidad total.

Tabla No.5. *Niveles máximos, mínimos y promedio de alcalinidad registrados por estrato en cada estanque de cultivo de tilapias gift Oreochromis niloticus*

Alcalinidad ($CaCO_3$mg/l)	Estaque No.1						Estanque No.3						Estanque No.4					
	Superficie		Medio		Fondo		Superficie		Medio		Fondo		Superficie		Medio		Fondo	
	a.m.	p.m.	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m	a.m.	p.m	a.m	p.m	a.m	p.m
Valor mínimo	142	142	144	144	132	126	142	144	120	136	132	138	142	144	144	144	142	144
Valor máximo	226	204	210	198	216	204	198	196	204	202	198	202	204	202	198	200	198	208
Promedio	177.1	176.5	175.3	176.2	175.6	175.1	170.0	169.8	168.7	169.3	169.3	170.2	174.9	176.8	174.8	177.0	174.9	177.1

A diferencia de los otros parámetros de calidad de agua ya descritos, la alcalinidad se mantuvo dentro de los rangos recomendados para el cultivo de tilapia; no se presentó diferencia entre los estratos, entre los tiempos de medición, ni entre los estanques.

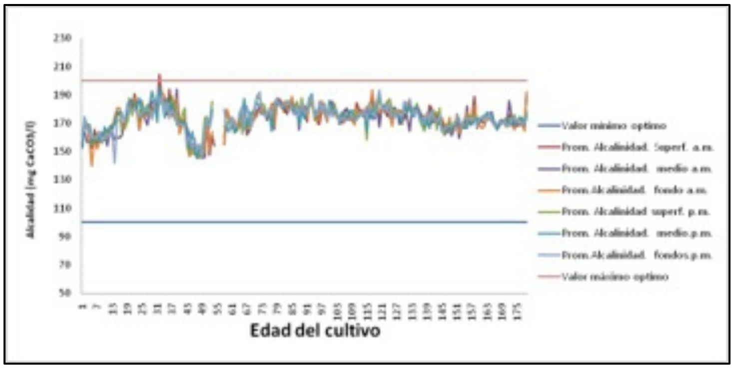

***Fig. No.9**. Comportamiento de la Alcalinidad en el estrato superficial, medio y fondo del promedio de los tres estanques de cultivo de tilapias gift <u>Oreochromis niloticus.</u>*

Los resultados de alcalinidad realizados semanalmente en laboratorio, según el test de ANOVA, indica que no hubo diferencias significativas entre los estanques ($p>0.05$) ni entre los días de cultivo. Al realizarse un análisis de correlación con la clorofila a se encontró una correlación positiva ($r = 0.53$) con la alcalinidad total.

Productividad primaria: Se observó que la clorofila *a,* aumentó a partir del día 29 de edad del cultivo, doce días después de la aplicación del fertilizante, la cual se mantuvo ascendente hasta los 110 días de cultivo para luego decaer y volver a subir hacia finales del cultivo. Estos incrementos de Clorofila *a*, coincidieron con el fósforo reactivo soluble, nitratos, nitrógeno amoniacal total, sólidos suspendidos, los cuales también aumentaron sin llegar a sobre pasar los rangos aceptables para cultivo. La prueba de ANOVA de un factor y el Test Post Hoc de comparación múltiple de los resultados de clorofila *a* de los tres estanques indican que no existió diferencia significativa ($p<0.05$) entre los estanques.

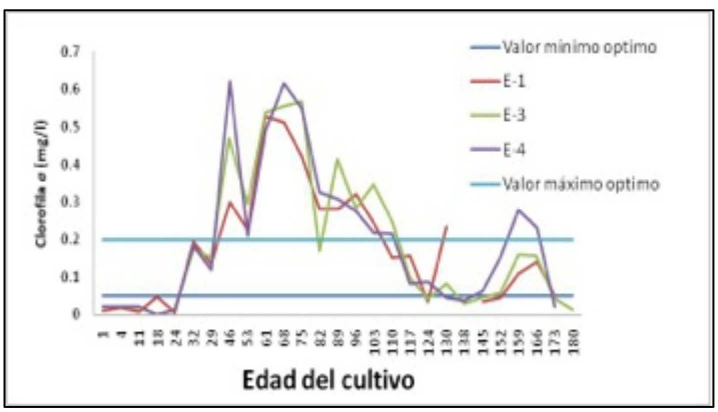

***Fig. No.10.** Comportamiento de la Clorofila a en cada estanque de cultivo de tilapias gift <u>Oreochromis niloticus.</u>*

Según Boyd (1998), los estanques de producción acuícola comúnmente tienen concentraciones de clorofila *a*, entre 0.05 mg/l a 0.2 mg/l. En este estudio se registraron concentraciones hasta 0.6 mg/l muy por encima del nivel indicado, este incremento de la productividad primaria se dio a efectos de la fertilización con NPK y posiblemente por una acumulación de alimento no consumido, generando una sobre fertilización de los estanques. Donde a finales del estudio podemos observar que los estanques que tenían mayor clorofila a, son los que tenían menos peces en los estanques.

El incremento de la productividad primaria con su consecuente sombreado (Egna. H & Boyd, C. 1997) incidieron en una disminución de la penetración de la luz solar en la columna de agua, manteniéndose una visibilidad del disco sechi entre los 15 a 30 cm de a partir de los 34 días de edad del cultivo hasta su culminación.

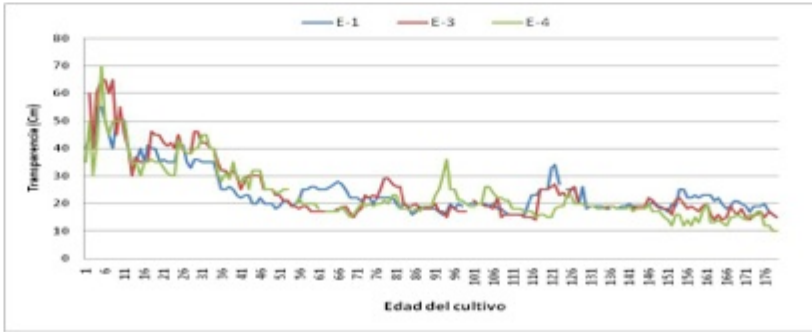

Fig. No.11. *Comportamiento de la transparencia del agua en cada estanque de cultivo de tilapias gift* *Oreochromis niloticus.*

Fósforo reactivo soluble (fosfatos) y fósforo total: Son productos resultantes de la actividad biológica de los peces y de la sobrealimentación con alimentos balanceados. La concentración alta, causa aumento en la población de fitoplancton; y éstas a su vez, provocan bajas de oxígeno por la noche. Su valor debe fluctuar entre 0.6 y 1.5 ppm como PO_4, su toxicidad aumenta a valores de pH ácido (NICOVITA s.f). En todo momento los valores de fósforo reactivo soluble se mantuvieron por debajo de lo recomendado, aunque fue evidente el incremento de éste a partir de la fertilización realizada en el día 17, donde el E-3 presentó la mayor variación, mientras que el E-4 aumentó de forma gradual.

El fósforo total: Este raramente excede los 0.5 mg/l y a menudo es menor a 0.1 mg/l (Egna & Boyd. 1997). Los resultados obtenidos evidencian un incremento en las concentraciones de éste parámetro a partir de la fertilización en los estanques, registrando valores máximos de 0.98 mg/l. El fósforo como un macro elemento en el alimento juega un papel central en el metabolismo celular y energético de los peces, por lo tanto si éste no es consumido por los peces queda como material insoluble en el agua aumentando la concentración de éste elemento y al no haber recambio de agua se produce un efecto acumulativo. El fósforo soluble proveniente del fertilizante se encuentra en bajas concentraciones debido a que es absorbido por el fitoplancton (Boyd.1982) y esto se demuestra con el aumento de clorofila *a* en los tres estanques. Este fósforo soluble absorbido por el fitoplancton es cuantificado en el fósforo total, por tanto aumenta también la concentración de este parámetro.

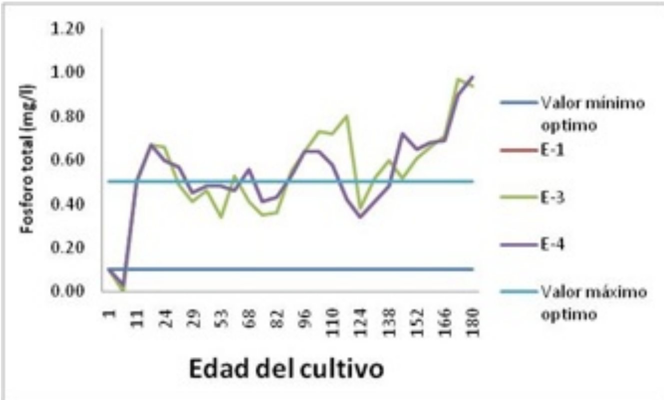

Fig. No.12. *Comportamiento del fósforo total en el agua en cada estanque de cultivo de tilapias gift Oreochromis niloticus.*

Nitritos: Es un parámetro de vital importancia por su gran toxicidad y por ser un poderoso agente contaminante. Se generan en el proceso de transformación del amoníaco a nitratos. Su toxicidad depende de la cantidad de cloruros, temperatura y concentración de oxígeno en el agua. Es necesario mantener la concentración por debajo de 0.1 ppm, haciendo recambios fuertes, limitando la alimentación y evitando concentraciones altas de amonio en el agua (NICOVITA. S.f). Todos los resultados de nitrito mantuvieron por debajo de los valores recomendados, con un máximo de 0.011 mg/L que se registro en el E-3. El nitrito es la primera sustancia inorgánica que se forma por la nitrificación (Arredondo & Ponce. 1998). Estos resultados indican que no hubo acumulación de materia orgánica nitrogenada en los estanques en estudio.

Nitrato: Las concentraciones de nitrato registradas en todos los estanques estuvieron dentro de los rangos permisibles recomendados por Boyd (1998) de 0.2 a 10.0 mg/l, lo que nos podría indicar que los procesos de nitrificación se están dando a muy pequeña escala, debido a la poca materia orgánica nitrogenada y las altas concentraciones de oxígeno (Arredondo & Ponce, 1998).

Nitrógeno amoniacal total ($NH_4^+ + NH_3$): El nitrógeno amoniacal lo constituye el nitrógeno amoniacal ionizado (amonio) y el nitrógeno amoniacal no ionizado (amoniaco). El amonio es un producto de la excreción, orina de los peces y descomposición de la materia (degradación de la materia vegetal y de las proteínas del alimento no consumido). El amonio no ionizado (forma gaseosa) y primer producto de excreción de los peces, es un elemento tóxico. La toxicidad del amonio en forma no ionizada (NH_3), aumenta cuando la concentración de oxígeno disuelto es bajo, el pH altos (alcalino) y la temperatura alta. Cuando los valores de pH son bajos (ácidos), el amonio no causa mortalidades. Los valores de amonio deben fluctuar entre 0.0 1 mg/l a 0.1 mg/l (valores cercanos a 2 ppm son críticos). Los niveles de tolerancia para la tilapia se encuentran en el rango de 0.6 a 2.0 mg/l. La concentración alta de amonio en el agua causa bloqueo del metabolismo, daño en las branquias, afecta el balance de sales, produce lesiones en órganos internos, inmuno supresión y susceptibilidad a las enfermedades, reducción del crecimiento y sobrevivencia, exolftalmia (ojos brotados) y ascitis (acumulación de líquidos en el abdomen) (NICOVITA s.f).

Los resultados obtenidos de nitrógeno amoniacal total no presentó ningún valor por encima del rango permisible (0.2-2.0 mg/l) según Boyd (1998). Este parámetro muestra un comportamiento similar al del nitrito y nitrato, donde su baja concentración puede indicar baja concentración de materia orgánica nitrogenada. No se evidenció diferencias significativas entre los estanques ($p>0.05$).

El nitrógeno amoniacal no ionizado (amoníaco, NH_3) presentó el mismo comportamiento que el nitrógeno amoniacal total, un único valor de 0.09 mg/l se presentó en el E-4 a los 145 días de cultivo, cercano al límite permisible de 0.1 mg/L indicado por Boyd (1998), esto podría deberse a la presencia de excretas.

Sólidos suspendidos totales (SST): A medida que se desarrollo el cultivo los niveles de SST fueron aumentando, manteniéndose por lo general por encima de los rango (10-50 mg/L) sugerido por Boyd (1998), Valores más altos se presentaron posterior a la disminución de la productividad primaria, medida a través de la clorofila *a,* lo cual pudo haber influido su incremento, así como el incremento de excreta, donde E-1, con mayor población presentó mayor SST al final del cultivo.

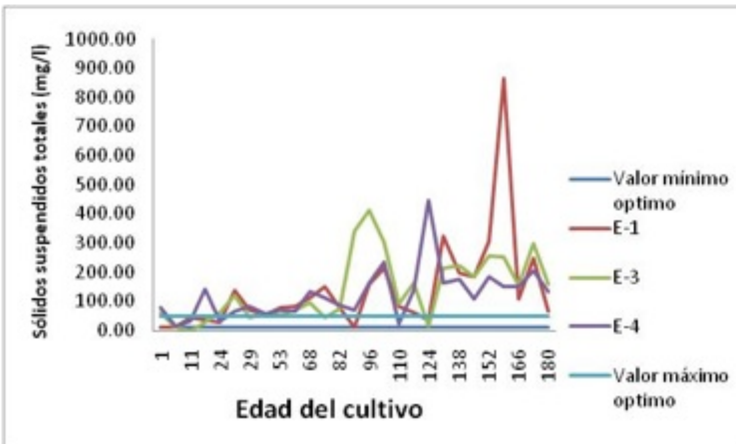

Fig. No.13. *Comportamiento de los sólidos suspendidos totales en el agua en cada estanque de cultivo de tilapias gift* *Oreochromis niloticus.*

Sólidos disueltos totales: están constituidos por todos los electrolitos capaces de conducir la corriente eléctrica. En este estudio los sólidos disueltos totales manifestaron una disminución con respecto al día cero de cultivo. Esto puede deberse a la asimilación de electrolitos por el fitoplancton, como lo expresa (Arredondo & Ponce, 1998).

3.2 ESTRATIFICACIÓN DE LA COLUMNA DE AGUA

Temperatura: Según el análisis de las diferencias mínimas significativas de la temperatura (°C) medidas en los nueve puntos de la columna de agua en tres momentos de cultivo (0, 90 y 180 días de cultivo), indican que existió cuatro estratos de temperatura en la columna del agua, las cuales no difirieren entre sí en más de 1.95°C (ver tabla No.6, en anexo No.1).

Un primer estrato y con valores más altos de temperatura (28.50°C) se registró en los primeros 50 cm de la columna de agua, el cual es significativamente diferente al resto, un segundo estrato se ubicó entre los 50 y 60 cm, iguales entre sí (28.43°C), pero significativamente diferente al resto de la columna, mientras que la temperatura del estrato ubicado a los 70 cm indica diferencia significativa con toda la columna del agua, aunque gráficamente su promedio se comporta igual al estrato de 80-90 cm, donde ambos presentan los valores más bajos de temperatura (28.25°C).
Es importante señalar que las diferencias de temperatura en los distintos estratos de la columna de agua se registran entre las 9a.m. y 4p.m., lo cual indica una acción directa de la energía del sol, donde en ausencia de éste la temperatura fue igual en toda la columna de agua.

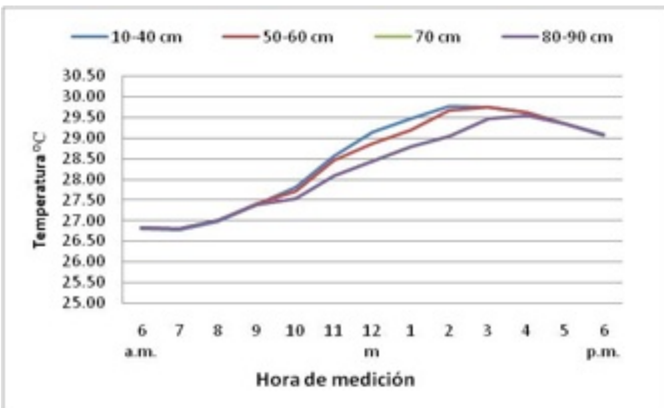

Fig. No.14. Gradientes de temperatura significativamente diferentes en la columna del agua

Esta acción directa del sol también se evidencia en el resultados de los tres momentos de medición, donde se encontró que al 0 día de cultivo se registró la mayor temperatura en todas las mediciones, con diferencias entre 0.38 a 1.08 °C. Esto se debió a una menor productividad primaria y por tanto hubo una mayor incidencia de los rayos solares en toda la columna del agua en los tres estanques.

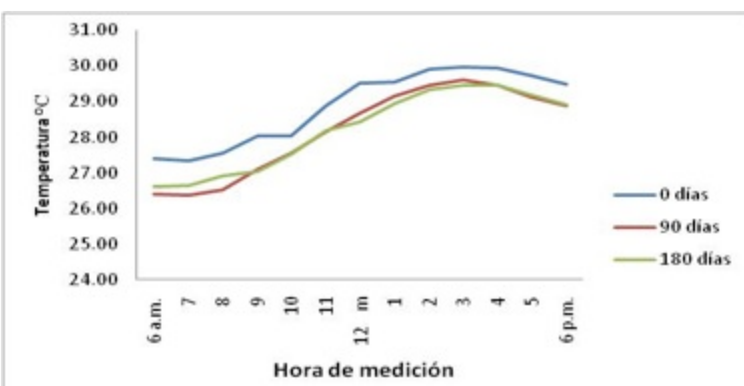

***Fig. No.15.** Comportamiento de la temperatura en los tres momentos de medición en los estanques de cultivo.*

Por otro lado se encontró que a los 90 días se registró la mayor variabilidad de temperatura entre los diferentes estratos, seguido de la medición a los 180 días de cultivo (*Fig. No.16)*, presentándose diferencias significativas ($p<0.05$) entre las tres los días de cultivo. Lo cual coincidió con el periodo donde los tres estanques presentaron alta variabilidad en la concentración de oxígeno disuelto en el día (>15 mg/l) y por la noche (< 3mg/l), por efecto alta productividad primaria, por lo cual fue necesario adicionar agua para disminuir la densidad poblacional de fitoplanctónica.

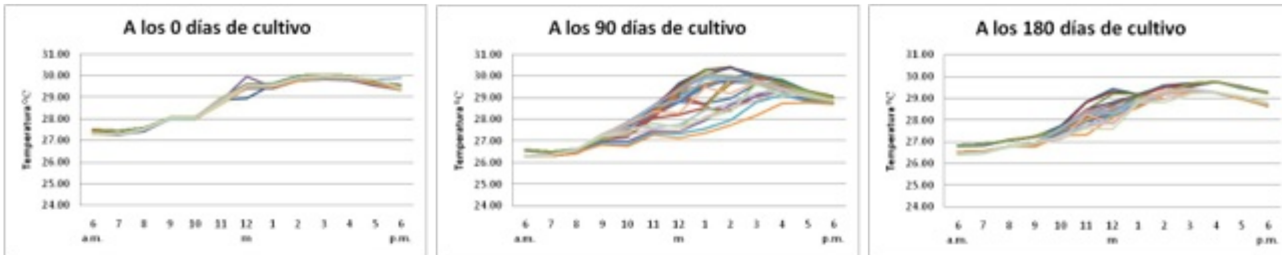

Fig. No.16. *Comportamiento de la temperatura en cada momento de cultivo 0, 90 y 180 días de cultivo, medidos en nueve estratos de la columna de agua en los tres estanques (E-1, E-3 y E-4).*

Para demostrar si hubo diferencias significativas de temperatura entre los estanque, se aplicó un test de homogeneidad de varianzas y ANOVA de un factor, indicando los resultados que no hay diferencia significativa entre los estanques ($p>0.05$).

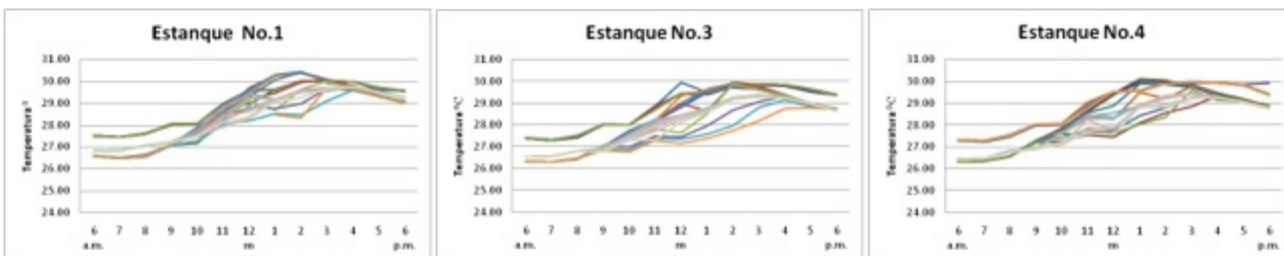

Fig. No.17. *Comportamiento de la temperatura en cada estanques E-1, E-3 y E-4, medidos en nueve estratos de la columna de agua en tres momentos del cultivo (0, 90 y 180 días de cultivo).*

Oxígeno disuelto: Al igual que la temperatura, la concentración de oxígeno disuelto (mg/l) presentó cuatro diferentes gradientes, el primero se registró en los primeros 10 cm de la columna de agua, el que es similar al registrado entre los 60 a 70 cm con concentraciones de 9.72 mg/l. La mayor concentración de oxígeno disuelto (10.21mg/l) se registró en los estrato de 20 a 60 cm de profundidad. El estrato con menos concentración de oxígeno disuelto (9.44 mg/l) se encontró entre los 80 a 90 cm (ver tabla No.7, en anexo No.1).

Las diferencias de concentración de oxígeno disuelto en los distintos estratos de la columna de agua se registraron en presencia de la luz solar (entre las 9 a.m. y 6 p.m.), lo cual indica una acción directa de la energía del sol, donde en ausencia de éste el oxígeno fue igual en toda la columna de agua.

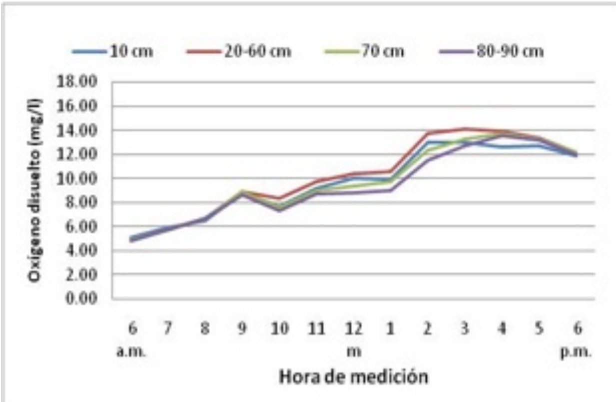

Fig. No.18. *Gradientes del oxígeno disuelto significativamente diferente en la columna del agua*

El comportamiento del oxígenos disuelto fue directamente proporcional a la abundancia de productividad primaria, siendo más estable y con concentraciones intermedias al 0 día de cultivo (9.35 mg/l), mientras que a los 90 días de edad del cultivo se presentó la mayor concentración de oxígeno disuelto (11.84 mg/l) (fertilización) y a los 180 días presentó el promedio más bajo de oxígeno disuelto (8.68 mg/l) y fue altamente variable la concentraciones de oxígeno disuelto de la mañana con respecto a la tarde. Mayor consumo de oxígeno.

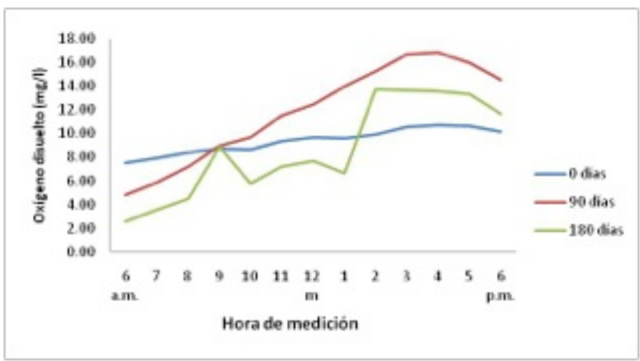

Fig. No.19. *Comportamiento del oxígeno disuelto en los tres momentos de medición en los estanques de cultivo.*

Se aplicó un test de homogeneidad de varianzas y ANOVA de un factor, indicando los resultados que hay diferencia significativa en el E-3 ($p<0.05$) con respecto a los otros dos estanques, donde además fue el estanque que presento mayor diferencia de oxígeno disuelto entre la medida a los 90 y 180 días y el más bajo nivel de oxígeno disuelto medido en la mañana del día 180.

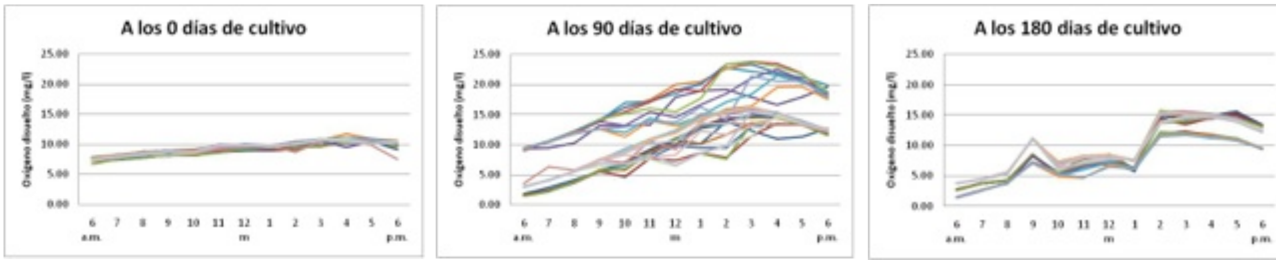

Fig. No.20. *Comportamiento del oxígeno disuelto en cada momento de cultivo 0, 90 y 180 días de cultivo, medidos en nueve estratos de la columna de agua en los tres estanques (E-1, E-3 y E-4).*

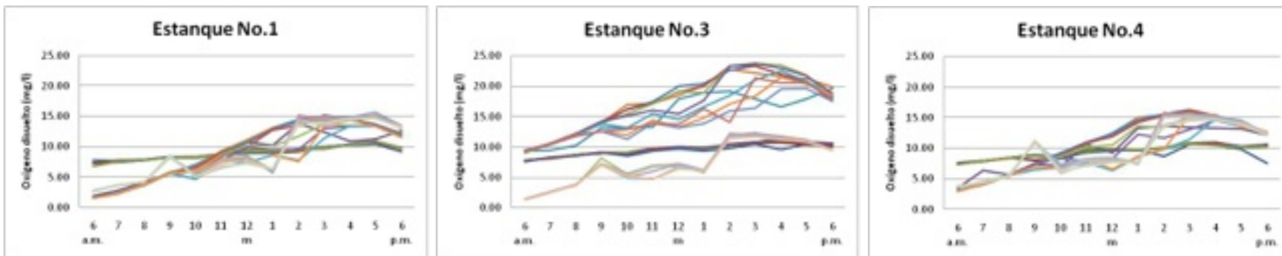

Fig. No.21. *Comportamiento del oxígeno disuelto en cada estanques E-1, E-3 y E-4, medidos en nueve estratos de la columna de agua en tres momentos del cultivo (0, 90 y 180 días de cultivo).*

Potencial de hidrógeno (pH)

El análisis estadístico indica que el pH fue significativamente diferente entre el estrato superficial (10 a 30 cm), medio (40 a 60 cm) y fondos (70 a 90 cm), sin embargo dentro de los estratos, compartían características con el nivel superior o inferior inmediato. El pH más alto se registró en los primeros 30 cm con 8.85, seguido de la parte media con 8.69 y con un pH de 8.55 en el fondo (ver tabla No.8, en anexo No.1).

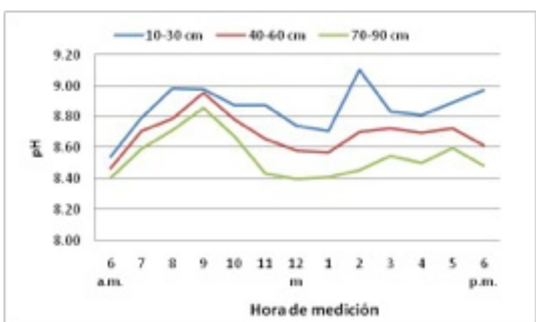

Fig. No.22. *Gradientes de pH significativamente diferente en la columna del agua*

Al 0 día de cultivo el pH promedio fue de 7.62, a los 90 dias de cultivo fue de 9.02 y a los 180 dias de cultivo llego a 9.42, es decir que ha medida que incrementaba la actividad biológica el pH se tornó más básico.

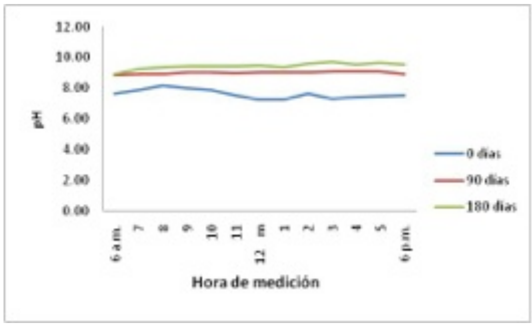

Fig. No.23. Comportamiento del pH en los tres momentos de medición en los estanques de cultivo

Como se puede observar en la siguiente figura y según la prueba t Student (tcal > t crítico) existió diferencias significativas entre los días de cultivo y entre el comportamiento diario del pH, principalmente en los días 90 y 180, no así entre los estanque.

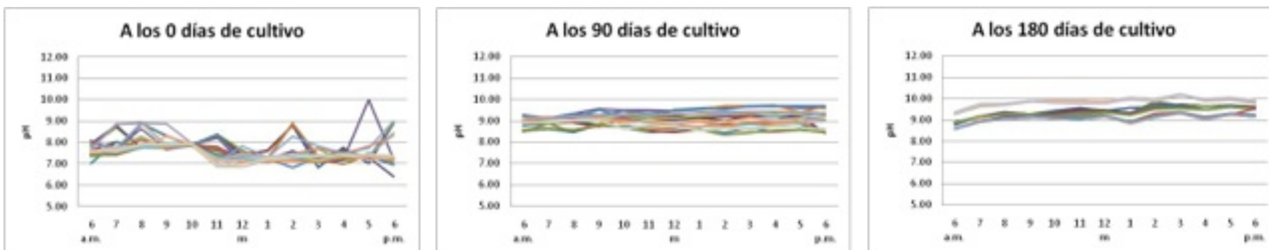

***Fig. No.24.** Comportamiento del pH en cada momento de cultivo 0, 90 y 180 días de cultivo, medidos en nueve estratos de la columna de agua en los tres estanques (E-1, E-3 y E-4).*

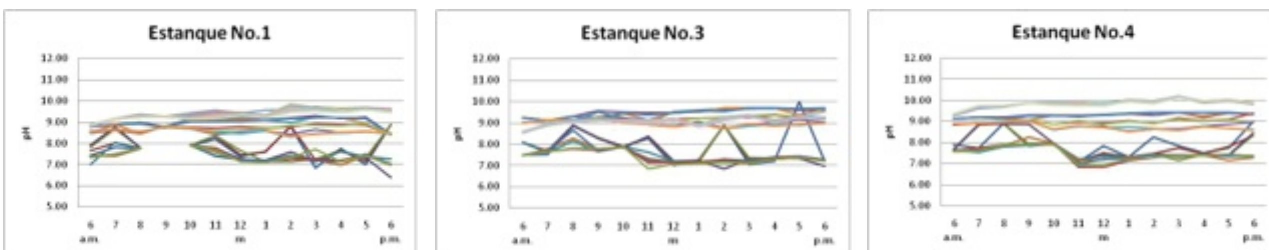

***Fig. No.25.** Comportamiento del pH en cada estanques E-1, E-3 y E-4, medidos en nueve estratos de la columna de agua en tres momentos del cultivo (0, 90 y 180 días de cultivo).*

Egna H & Bord C. (1997), indican que además de los efectos estacionales, la temperatura del agua puede exhibir una estratificación vertical en los estanques tropicales pocos profundos. En muchos estanques el agua se estratifica, porque la superficie se calienta durante el día y los vientos son limitados. Esta estratificación puede ser rota en el mismo día por los vientos y las lluvias.

3.4 NIVELES BACTERIANOS EN EL CULTIVO

Estanque No.1

Echeriachia coli: No existe un nivel máximo permisible para la bacteria E, coli dentro de un estanque de cultivo de peces. Esta bacteria es el mayor representante del grupo de los coliformes fecales, por tanto se toma como referencia el mismo nivel permisible < 1,000 NMP/100ml.

Se observó que los niveles de E. coli estuvieron dentro de los niveles permisibles en 100% de todas las muestras analizadas, donde se registró un valor mínimo de 1.8 NMP/100ml y un valor máximo de 130 NMP/100ml. No se observaron correlaciones positivas o negativas con los parámetros oxígeno, temperatura y pH en los tres estratos de la columna de agua, tampoco se observó correlación con la sobrevivencia de los peces.

Coliformes totales y fecales: El 85.7 % de todas las muestras de agua analizadas para éste grupo de bacterias se encontraron dentro de los niveles permisibles y el 100 % para los coliformes fecales. Los coliformes totales registraron un valor mínimo de 11.34 NMP/100ml y un máximo de 1600 NMP/100ml, mientras que los coliformes fecales registraron un mínimo de 5,6 NMP/100ml y un máximo de 130 NMP/100ml. Solamente los coliformes totales presentaron una correlación significativa a nivel $P<0.05$ con la variable del pH del fondo del estanque.

Enterococcus: Los resultados obtenidos demuestran que el 42.8 % de todas las muestras de agua analizadas de este estanque estuvieron por encima de los niveles permisibles, registrando un valor mínimo de 2 NMP/100ml y un valor máximo de 63 NMP/100ml; no se observó correlación significativa con los parámetros de oxígeno, temperatura, pH y sobrevivencia de peces.

Pseudomonas: son bacterias gram negativas, patógenas oportunistas, es parte de la flora normal del agua dulce así como del intestino de peces sanos y enfermos (Angeline & Seigneur, 1988), (Roberts, 1989), (Eissa, Abou El Ghiet, Shaheen, & Abbass, 2010). Solo existen niveles permisibles de estas bacterias para aguas embotelladas. En este estanque se registró un valor mínimo de < 1.8 NMP/100ml y un valor máximo de 1600 NMP/100ml. Observándose únicamente una correlación significativa con la variable de pH de la superficie de la columna de agua (ver tabla 4).

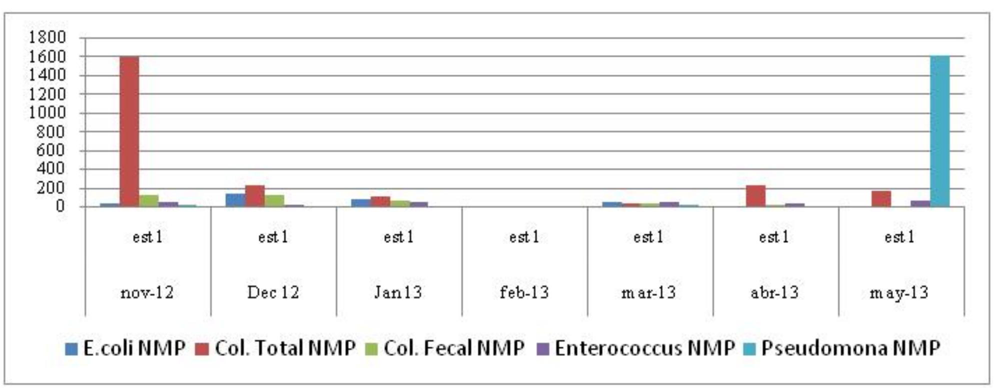

Fig. No.26. *Resultados bacteriológica en el Estanque No.1 de de cultivo de tilapias gift Oreochromis niloticus.*

***Tabla No.9**. Análisis de correlación de bacterias con parámetros físico-químicos y la sobrevivencia de la tilapias gift Oreochromis niloticus del Estanque No.1*

	E. coli	Col. Total	Col. Fecal	*Enterococcus*	*Pseudomona*
O_2Sup.	.112	-.008	-.167	.455	.167
O_2Med.	.247	-.369	-.311	.413	.164
O_2Fond.	.382	-.335	-.207	.504	.152
T°Sup.	.217	.031	.232	-.159	-.329
T°Med.	.252	.041	.243	-.164	-.332
T°Fond.	.252	.037	.240	-.164	-.329
pHSup.	.038	.180	.310	-.129	**-.586***
pHMed.	-.105	.189	-.044	-.148	-.461
pH Fon.	-.269	**.609***	.140	.030	-.105
Sobrevivencia	.530	-.126	.190	-.167	-.275

*Correlación es significativa al nivel de 0.05 (bilateral)

Estanque No.3

Echeriachia coli: El 100% de todas las muestras de agua analizadas de este estanque registraron niveles permisibles de E. coli. Se observó un valor mínimo de 2 NMP/100ml y un máximo de 49 NMP/100ml, no se observaron correlaciones significativas con los parámetros de oxígeno, temperatura y pH en los tres estratos de la columna de agua, tampoco se observó correlación con la sobrevivencia de los peces.

Coliformes totales y fecales: Solamente el 14.28% de los resultados obtenidos de coliformes totales estuvieron por encima de los niveles permisibles, mientras que el 100% de las muestras analizadas para coliformes fecales estuvieron dentro de los límites permisibles. Se obtuvo un valor mínimo de 22 NMP/100ml de coliformes totales y de 2 NMP para coliformes fecales, un valor máximo de 1,600 NMP/100ml para coliformes totales y de 43.8 NMP/100ml para coliformes fecales, únicamente se registró correlación significativa con el parámetro del pH del fondo del estanque.

Enterococcus: Son cocos gram positivos que se encuentran aislados en pares o formando cadenas cortas. Son indicadores de contaminación fecal al igual que los coliformes y E. coli y, junto a estas bacterias es un organismo patógeno tanto para los peces como para los seres humanos (Martins, y otros, 2009). El 42.8 % de todas las muestras de agua de estanque analizadas estuvieron por encima del nivel permisible, se registró una valor mínimo de 11 NMP/100ml y un valor máximo de 220 NMP/100ml, no se observó correlación significativa con las variables de pH, oxígeno, temperatura y sobrevivencia de los peces.

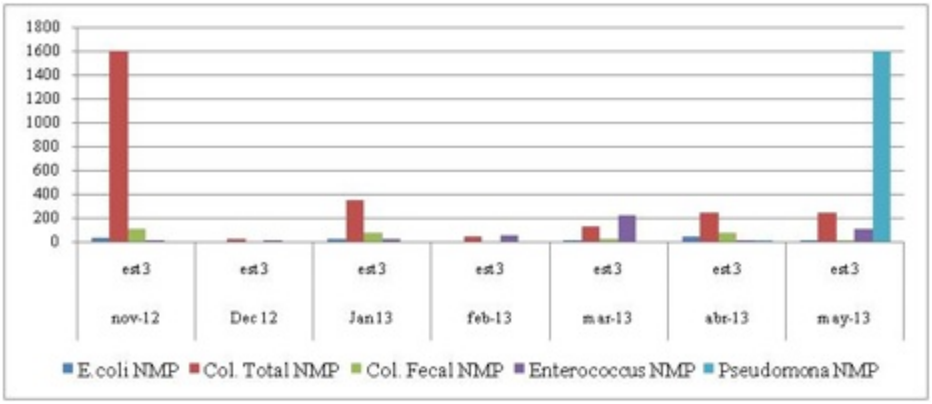

Fig. No.27. *Resultados bacteriológica en el Estanque No.3 de de cultivo de tilapias gift Oreochromis niloticus.*

Tabla No.10. *Análisis de correlación de bacterias con parámetros físico-químicos y la sobrevivencia de la tilapias gift Oreochromis niloticus del Estanque No.3*

	E. coli	Col. Total	Col. Fecal	Enterococcus	Pseudomona
O_2Sup.	-.147	-.272	-.427	.315	.387
O_2Med.	.228	.579	.237	.751	.419
O_2Fond.	.071	.366	.111	.124	.337
T°Sup.	-.174	.310	.272	-.348	-.675
T°Med.	-.161	.320	.285	-.362	-.677
T°Fond.	-.150	.327	.297	-.390	-.676
pHSup.	.548	.194	.560	-.148	**-.886***
pHMed.	-.429	-.139	-.144	-.247	-.464
pH Fon.	-.303	-.213	-.023	-.327	-.441
Sobrevivencia	-.070	.535	.350	-.484	-.612

*Correlación es significativa al nivel de 0.05 (bilateral)

Estanque No.4

Echeriachia coli: No se observó que alguna de las muestras de agua tomadas de este estanque estuvieran por encima del nivel permisible de E. coli, se registró un valor mínimo de < 1.8 NMP/100ml y un valor máximo de 920 NMP/100ml, no se encontró correlación significativa con ninguna de las variables temperatura, oxígeno, pH y sobrevivencia de los peces.

Coliformes totales y fecales: Se registró el mismo porcentaje de muestras que sobrepasaron el nivel permisible de coliformes totales y fecales del 14.28 %, el valor mínimo registrado fue de 13 NMP/100ml para coliformes totales y de < 1.8 NMP/100ml para coliformes fecales, el valor máximo obtenido fue de 1600 NMP/100ml tanto para coliformes totales como para coliformes fecales. De estos dos grupos de bacterias solamente los coliformes totales tuvieron una correlación significativa con una de las variables estudiadas, la de supervivencia de los peces.

Enterococcus: La mayoría de los resultados obtenidos de los Enterococcus estuvieron dentro de los límites permisibles, solamente el 28.6% de ellos estuvieron por encima de los límites, registrándose un valor mínimo de < 1.8 NMP/100ml y un valor máximo de 280 NMP/100ml. Se encontró una fuerte correlación entre este grupo de bacterias y la variable de oxígeno en los estratos superficie y medio del estanque.

Pseudomonas: Las bacterias Pseudomonas registraron un valor mínimo de < 1.8 NMP/100ml y un valor máximo de 1600 NMP/100ml en este estanque.

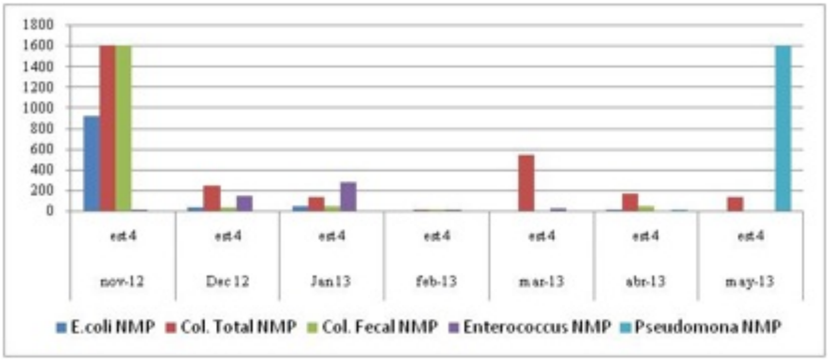

Fig. No.28. *Resultados bacteriológica en el Estanque No.4 de de cultivo de tilapias gift Oreochromis niloticus.*

Tabla No.11. *Análisis de correlación de bacterias con parámetros físico-químicos y la sobrevivencia de la tilapias gift Oreochromis niloticus del Estanque No.4*

	E. coli	Col. Total	Col. Fecal	Enterococcus	Pseudomona
O_2Sup.	-.065	-.048	-.020	.838*	.344
O_2Med.	-.216	-.326	-.295	.937*	.513
O_2Fond.	-.262	.100	.111	.446	-.324
T°Sup.	.253	.617	.502	-.366	-.682
T°Med.	.253	.615	.501	-.388	-.686
T°Fond.	.241	.608	.499	-.364	-.692
pHSup.	.318	.543	.464	.294	.449
pHMed.	.439	.588	.322	.212	-.384
pH Fon.	-.298	.167	.385	-.071	-.482
Sobrevivencia	.597	.890**	.598	-.374	.610

*Correlación es significativa al nivel de 0.05 (bilateral)
**Correlación es significativa al nivel de 0.01 (bilateral)

Resultado en los tejidos y órganos de las tilapias
Los análisis bacteriológicos en alevines indicaran presencia de la bacterias *Pseudomonas spp,* no así para la bacteria *Aeromonas spp*.

Los análisis realizadas a los 90 días de cultivo para bacterias de E. coli, coliformes totales, fecales, *Enterococcus y Pseudomonas*, reportaron valores de < 3 NMP/g. Adicionalmente se encontró presencia de *Aeromona schubertii* en los órganos internos, en muestras del E-3.

A los 180 días de cultivo se encontró las bacterias E. coli, coliformes fecales, *Enterococcus y Pseudomonas* en el tejido en 15 peces recolectados en los tres estanques, los cuales estuvieron en < 3 NMP/g; únicamente coliformes totales estuvieron por encima de esos niveles permisibles, en el E-1 con valores de 23 NMP/g y el E-4 con 43 NMP/g, donde además se observó peces con apariencia de enfermos presentando signos de descamación, ojos resaltados, piel oscura, manchas rojas en las aletas y área anal. En los órganos internos de los peces se encontró *Pseudomona putida, Aeromona veroniibv veronii y Aeromona spp.gr 501*

Como podes ver hubo presencia bacteriana en los diferentes estanques y en los diferentes momentos de análisis de los tejidos. Las bacterias coliformes totales, coliformes fecales, *Enterococcus y E. coli* llegan a las fuentes de agua por la contaminación con excretas humanas o escorrentías de granjas de ganado vacuno, porcino etc., (Yagoub & Ahmed, 2004), (Stoddard, Coyne, & Grove, 1998)(Kress & Gifford, 1984)(Van Donsel, Geldreich, & Clarke, 1967). Para esta investigación se utilizó agua de pozo sin tratamiento previo. Esto podría explicar el por qué en el primer muestreo de agua se registraron niveles mayores de 1600 NMP/100ml de coliformes totales y fecales.

Inicialmente se consideraba a la tilapia como un pez resistente al ataque de bacterias, virus, parásitos y hongos, pero en estudios recientes se ha demostrado que no es tan resistente especialmente cuando hay factores de estrés (Klesius, Shoemaker, & Evans, 1999)(Rey, Verjan, Ferguson, & Iregui, 2009). Las entero bacterias como los coliformes fecales, E. coli y *Enterococcus fecales*, son agentes infecciosos en los cuerpos de agua y pueden estar presentes en los tejidos de los peces. Cuando se presentan factores de estrés pueden ocasionar serios brotes epidemiológicos y mortalidades entre ellos (Newaj, Mutani, Ramsubhag, & Adesiyun, 2008) (Sekar, Santiago, Vijayan, Alavandi, & Raj, 2008). La transmisión de los patógenos se piensa que es horizontal y es a través de heridas y lesiones en los peces (Xu, Shoemaker, & Klesius, 2007). Varios autores han reportado la presencia de E. coli, coliformes fecales*, Enteroccocus y Aeromonas* en la piel de tilapias comercializadas (Thampuran, Surendraraj, & Surendran, 2005), (Heinitz, Ruble, Wagner, & Tatini, 2000), (Morales, Blanco, Arias, & Chaves, 2004), (Herrera & Santos, 2005).

En los resultados de los tres estanques, se encontró la presencia de todas estas bacterias, tanto en las muestras de agua como en las muestras de tejido. En casi todos los casos los niveles registrados estuvieron dentro de los límites permisibles. No se observaron mortalidades asociadas con estas bacterias, ni se observaron factores de estrés en los diferentes estanques. Al final del ciclo productivo se observó una disminución de los niveles de estas bacterias en el agua de los tres estanques, algunos autores refieren que puede haber una reducción de hasta el 90% de los niveles de estas bacterias en el agua de los estanques debido a diferentes factores como: sedimentación, cambios químicos, la acción germicida de la luz solar en el estrato superior de la columna de agua, así como la destrucción de las bacterias por los protozoos dotados de movimientos libres (Cruz, y otros, 2006) (Carnicross & Mara, 1990) (Cox, 1966).
En el análisis de los órganos internos se encontró presencia de *Pseudomonas spp y Aeromonasspp.,* estas bacterias son parte de la flora bacteriana de los peces de agua dulce del trópico (Sugita, Tokuyama, & Deguchi, 1985). Las *Pseudomonas* pueden representar cerca del 10% de la flora bacteriana de la piel de los peces (Shewan, 1977), tanto las *Aeromonas* como las *Pseudomonas* son bacterias predominantes en los intestinos de los peces (Sakata, Uno, & Kakimoto, 1984)(Vásquez, Rondón, Restrepo, & Eslava, 2010) y son organismos oportunistas que afectan a los peces cuando estos presentan signos de estrés, provocando septicemia y hemorragias internas que terminan conllevando a la muerte de los peces.

En el análisis de agua de los tres estanques se determinó que en el último muestreo a los 180 días de cultivo en todos ellos había niveles > 1,600 NMP/100 ml de *Pseudomonas*, esto podría deberse a una descomposición de la calidad del agua debido a factores como cero recambio de agua durante el cultivo, acumulación de materia orgánica, así como restos del alimento suministrado. Todos estos factores juntos crean un ambiente muy rico en nutrientes para las bacterias. Fue únicamente en el E-4, que mediante el análisis macroscópico de los peces, se observó mayor número de individuos con signos de afectación, tal como coloración oscura en la piel, manchas rojas en las aletas, descamaciones y ojos resaltados, siendo todos estos cuadros clínicos similares, ocasionados tanto por bacterias del género *Aeromonas* como *Pseudomonas.*

Los cambios que se producen desde la captura hasta la venta de los peces, pueden alterar sus condiciones físicas, químicas y microbiológicas y, si no se controla la cadena de frío puede ocasionar le reproducción de los microorganismo patógenos que se encuentran en la piel o en interior de los peces, principalmente la *Pseudomona y Aeromonas* organismos que pueden infectar a los seres humanos también, principalmente si los peces no se consumen correctamente cocidos (Daily, Joseph, Coolbaugh, Walker, & Merrell, 1981)(Joseph, Daily, Hunt, Seidler, & Allen, 1979).

CONCLUSIONES

Las condiciones de cero recambios de agua no fue posible mantener durante todo el cultivo debido a la necesidad de recuperar niveles de operación de los estanques a causa de pérdidas por filtración y evaporación. Así como por la necesidad de controlar las grandes fluctuaciones del oxígeno disuelto, dichos volúmenes de movimiento de agua no incurrieron en un aumento considerable de los costos de producción.

Los indicadores técnicos de cultivo son similares a los publicados como óptimos por otros autores, con crecimiento promedios de 517.74gr, sobrevivencia de 70.4% y FCA de 1.56. El E-1 reportó los mejores indicadores de cultivo, diferenciándose con los otros dos estanques, esto puede estar asociado a que es el estanque que tuvo mayor tiempo de maduración del agua[1], mejor eficiencia en el flujo del agua y el que se encuentra más próximo a la casa de técnico, lo cual disminuye el potencial ataque de aves.

La temperatura y oxígeno disuelto medidos en horas de la mañana se mantuvo fuera de los rangos aceptables para el cultivo de la tilapia. Sin embargo, la mayoría de parámetros físico-químicos estudiados semanalmente, presentaron valores dentro de los rangos recomendados por Boyd y NICOVITA, a excepción de ligeros aumentos en las concentraciones la clorofila *a*, fósforo total, sólidos suspendidos y altas fluctuaciones diurnas de pH y oxígeno disuelto, posiblemente influenciado por un bloom de fitoplancton y la acumulación de alimento no consumido por los peces.

No se encontró diferencias significativas en los parámetros físico-químicos del agua entre los estanques, por tanto no se considera que la calidad del agua haya influido en lo mejores indicadores técnicos de cultivo en el estanque E-1.
Todos los parámetros estudiados evidenciaron una estratificación de la columna del agua en los estanques, observándose a los 90 días de cultivo una marcada estratificación, donde además se presentó la mayor productividad primaria, la cual pudo contrarrestar los efectos directos de los rayos solares ya que se observó que a partir que disminuía la intensidad del sol los estratos desaparecían.

La presencia de bacterias no provocó la mortalidad de los peces durante el ciclo de cultivo debido a que no se presentaron factores extremos de calidad de agua que pudieran haber debilitado el sistema inmunológico de los peces en cultivo. Solamente en el E-4 se observan signos de enfermedad bacteriana al final del ciclo de cultivo provocado por la alta concentración de bacterias del género Pseudomonas influenciadas por la acumulación de materia orgánica.

Al no observar peces muertos en los estanques, la mortalidad registrados se asocia a la depredación por las aves, ya que no fue posible introducir la maya anti pájaros en los primeros meses de cultivo. El E-4 que se encuentra más alejado presentó el mayor porcentaje de mortalidad a diferencia del E-1 que se encuentra junto al plantel fue el que presentó la mayor tasa de sobrevivencia.
Estos resultados no indican que en condiciones de baja densidad de cultivo, es posible disminuir los costos de operación, generado por el movimiento de agua, sin que este afecte la calidad físicoquímica del agua, ni bacterilógica.

RECOMENDACIONES

- Posterior al llenado de estanques garantizar entre cuatro a seis días de reposo del agua
- No hacer usos de fertilizantes inorgánicos cuanto se hace uso de alimentos ricos en proteínas

[1] Estabilización de la productividad primaria

- Realizar medición de oxígeno disuelto por la noche en periodos donde la alta productividad de fitoplancton genera alta variabilidad del oxígeno entre el día y la noche y así de ésta manera poder determinar los periodos de exposición de los peces a bajas concentraciones de oxígeno.

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Anexo No.1.

Tabla No.6.

Comparaciones múltiples de temperatura de 0 a 90 cm de profundida, medidos a los 0, 90 y 180 dias de cultivo

Variable dependiente: Temperatura

DMS

(I) Estrato	(J) Estrato	Diferencia entre medias (I-J)	Error típ.	Significación
10	20	-.0258	.03196	.420
	30	-.0155	.03196	.629
	40	.0048	.03196	.881
	50	.0468	.03196	.144
	60	.0968*	.03196	.003
	70	.1631*	.03196	.000
	80	.2303*	.03196	.000
	90	.2271*	.03196	.000
20	10	.0258	.03196	.420
	30	.0103	.03196	.746
	40	.0306	.03196	.339
	50	.0726*	.03196	.023
	60	.1226*	.03196	.000
	70	.1889*	.03196	.000
	80	.2562*	.03196	.000
	90	.2529*	.03196	.000
30	10	.0155	.03196	.629
	20	-.0103	.03196	.746
	40	.0203	.03196	.526
	50	.0622	.03196	.052
	60	.1122*	.03196	.000
	70	.1785*	.03196	.000
	80	.2458*	.03196	.000
	90	.2426*	.03196	.000
40	10	-.0048	.03196	.881
	20	-.0306	.03196	.339
	30	-.0203	.03196	.526
	50	.0420	.03196	.190
	60	.0920*	.03196	.004
	70	.1583*	.03196	.000
	80	.2256*	.03196	.000
	90	.2223*	.03196	.000
50	10	-.0468	.03196	.144
	20	-.0726*	.03196	.023
	30	-.0622	.03196	.052
	40	-.0420	.03196	.190
	60	.0500	.03196	.118
	70	.1163*	.03196	.000
	80	.1836*	.03196	.000
	90	.1803*	.03196	.000
60	10	-.0968*	.03196	.003
	20	-.1226*	.03196	.000
	30	-.1122*	.03196	.000
	40	-.0920*	.03196	.004
	50	-.0500	.03196	.118
	70	.0663*	.03196	.038
	80	.1336*	.03196	.000
	90	.1303*	.03196	.000
70	10	-.1631*	.03196	.000
	20	-.1889*	.03196	.000
	30	-.1785*	.03196	.000
	40	-.1583*	.03196	.000
	50	-.1163*	.03196	.000
	60	-.0663*	.03196	.038
	80	.0673*	.03196	.036
	90	.0640*	.03196	.045
80	10	-.2303*	.03196	.000
	20	-.2562*	.03196	.000
	30	-.2458*	.03196	.000
	40	-.2256*	.03196	.000
	50	-.1836*	.03196	.000
	60	-.1336*	.03196	.000
	70	-.0673*	.03196	.036
	90	-.0032	.03196	.919
90	10	-.2271*	.03196	.000
	20	-.2529*	.03196	.000
	30	-.2426*	.03196	.000
	40	-.2223*	.03196	.000
	50	-.1803*	.03196	.000
	60	-.1303*	.03196	.000
	70	-.0640*	.03196	.045
	80	.0032	.03196	.919

Basado en las medias observadas.

*. La diferencia de medias es significativa al nivel .05.

Tabla No.7.

Comparaciones múltiples de oxigeno disuelto de 0 a 90 cm de profundida, medidos a los 0, 90 y 180 dias de cultivo

Variable dependiente: OXIGENO

DMS

(I) Estrato	(J) Estrato	Diferencia entre medias (I-J)	Error típ.	Significación
10	20	-.4964*	.17748	.005
	30	-.5523*	.17748	.002
	40	-.4587*	.17865	.010
	50	-.4109*	.17865	.022
	60	-.2180	.17865	.223
	70	.0674	.17865	.706
	80	.4005*	.17905	.026
	90	.7472*	.17426	.000
20	10	.4964*	.17748	.005
	30	-.0559	.17859	.754
	40	.0377	.17975	.834
	50	.0855	.17975	.634
	60	.2784	.17975	.122
	70	.5638*	.17975	.002
	80	.8969*	.18015	.000
	90	1.2436*	.17540	.000
30	10	.5523*	.17748	.002
	20	.0559	.17859	.754
	40	.0936	.17975	.603
	50	.1415	.17975	.431
	60	.3343	.17975	.063
	70	.6197*	.17975	.001
	80	.9528*	.18015	.000
	90	1.2996*	.17540	.000
40	10	.4587*	.17865	.010
	20	-.0377	.17975	.834
	30	-.0936	.17975	.603
	50	.0478	.18090	.792
	60	.2407	.18090	.184
	70	.5261*	.18090	.004
	80	.8592*	.18130	.000
	90	1.2059*	.17658	.000
50	10	.4109*	.17865	.022
	20	-.0855	.17975	.634
	30	-.1415	.17975	.431
	40	-.0478	.18090	.792
	60	.1929	.18090	.287
	70	.4783*	.18090	.008
	80	.8114*	.18130	.000
	90	1.1581*	.17658	.000
60	10	.2180	.17865	.223
	20	-.2784	.17975	.122
	30	-.3343	.17975	.063
	40	-.2407	.18090	.184
	50	-.1929	.18090	.287
	70	.2854	.18090	.115
	80	.6185*	.18130	.001
	90	.9652*	.17658	.000
70	10	-.0674	.17865	.706
	20	-.5638*	.17975	.002
	30	-.6197*	.17975	.001
	40	-.5261*	.18090	.004
	50	-.4783*	.18090	.008
	60	-.2854	.18090	.115
	80	.3331	.18130	.066
	90	.6798*	.17658	.000
80	10	-.4005*	.17905	.026
	20	-.8969*	.18015	.000
	30	-.9528*	.18015	.000
	40	-.8592*	.18130	.000
	50	-.8114*	.18130	.000
	60	-.6185*	.18130	.001
	70	-.3331	.18130	.066
	90	.3467	.17698	.050
90	10	-.7472*	.17426	.000
	20	-1.2436*	.17540	.000
	30	-1.2996*	.17540	.000
	40	-1.2059*	.17658	.000
	50	-1.1581*	.17658	.000
	60	-.9652*	.17658	.000
	70	-.6798*	.17658	.000
	80	-.3467	.17698	.050

Basado en las medias observadas.

*. La diferencia de medias es significativa al nivel .05.

Tabla No.8.

Comparaciones múltiples del pH de 0 a 90 cm de profundida, medidos a los 0, 90 y 180 dias de cultivo

Variable dependiente: PH

DMS

(I) Estrato	(J) Estrato	Diferencia entre medias (I-J)	Error típ.	Significación
10	20	.0000	.03283	1.000
	30	.0472	.03283	.151
	40	.0847*	.03283	.010
	50	.2272*	.03283	.000
	60	.2543*	.03283	.000
	70	.3098*	.03283	.000
	80	.3428*	.03283	.000
	90	.3560*	.03291	.000
20	10	.0000	.03283	1.000
	30	.0472	.03283	.151
	40	.0847*	.03283	.010
	50	.2272*	.03283	.000
	60	.2543*	.03283	.000
	70	.3098*	.03283	.000
	80	.3428*	.03283	.000
	90	.3560*	.03291	.000
30	10	-.0472	.03283	.151
	20	-.0472	.03283	.151
	40	.0374	.03283	.255
	50	.1800*	.03283	.000
	60	.2071*	.03283	.000
	70	.2626*	.03283	.000
	80	.2956*	.03283	.000
	90	.3087*	.03291	.000
40	10	-.0847*	.03283	.010
	20	-.0847*	.03283	.010
	30	-.0374	.03283	.255
	50	.1426*	.03283	.000
	60	.1697*	.03283	.000
	70	.2252*	.03283	.000
	80	.2582*	.03283	.000
	90	.2713*	.03291	.000
50	10	-.2272*	.03283	.000
	20	-.2272*	.03283	.000
	30	-.1800*	.03283	.000
	40	-.1426*	.03283	.000
	60	.0271	.03283	.410
	70	.0826*	.03283	.012
	80	.1156*	.03283	.000
	90	.1287*	.03291	.000
60	10	-.2543*	.03283	.000
	20	-.2543*	.03283	.000
	30	-.2071*	.03283	.000
	40	-.1697*	.03283	.000
	50	-.0271	.03283	.410
	70	.0555	.03283	.091
	80	.0885*	.03283	.007
	90	.1017*	.03291	.002
70	10	-.3098*	.03283	.000
	20	-.3098*	.03283	.000
	30	-.2626*	.03283	.000
	40	-.2252*	.03283	.000
	50	-.0826*	.03283	.012
	60	-.0555	.03283	.091
	80	.0330	.03283	.315
	90	.0462	.03291	.161
80	10	-.3428*	.03283	.000
	20	-.3428*	.03283	.000
	30	-.2956*	.03283	.000
	40	-.2582*	.03283	.000
	50	-.1156*	.03283	.000
	60	-.0885*	.03283	.007
	70	-.0330	.03283	.315
	90	.0131	.03291	.690
90	10	-.3560*	.03291	.000
	20	-.3560*	.03291	.000
	30	-.3087*	.03291	.000
	40	-.2713*	.03291	.000
	50	-.1287*	.03291	.000
	60	-.1017*	.03291	.002
	70	-.0462	.03291	.161
	80	-.0131	.03291	.690

Basado en las medias observadas.

*. La diferencia de medias es significativa al nivel .05.

TOPIC AREA:
EXPERIMENTAL POND UNIT ASSESSMENT

❖

EXPERIMENTAL POND UNIT ASSESSMENT IN SOUTHERN NEPAL

Production System Design & Best Management Alternatives/Activity/09BMA14UM

FINAL INVESTIGATION REPORT

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ABSTRACT

This pond characterization experiment had goals to evaluate ponds in Nepal for their physical, chemical, and biological characteristics during a grow-out; and to evaluate production characteristics of Nile tilapia (*Oreochromis niloticus*) in these ponds. Twelve earthen ponds were used with treatments including 4 control ponds receiving fertilization alone, 4 fully fed ponds with feed applied at 3% bw, and 4 combined ponds with both feed at 1.5% and fertilizer applied. All ponds were stocked a week after fertilization with sex-reversed Nile tilapia at 2 fish/m^2. Fertilizer was applied each week at 4 kg N and 1 kg P per hectare for fertilization treatments. Locally available feeds were used to feed twice daily in the morning and afternoon. Fish were stocked on 9 February 2013 and the experiment is ongoing. Fish growth in fertilized with half feeding ponds gave highest growth, followed by full feeding then fertilizer. Treatments that included fertilizer had higher pH, higher dissolved oxygen, lower Secchi disk, higher chlorophyll-a, higher total Kjeldahl nitrogen, higher total phosphorus, lower alkalinity, higher ammonium, higher soluble reactive phosphorus, and higher nitrite-N compared to only fed ponds. Fertilization with feeding produced the best growth conditions and best water quality consistently.

INTRODUCTION

A number of physical, chemical, and biological characteristics are important for the completion of quality experiments in ponds. The most obvious ones in physical characteristics include pond morphometry, pond depth, evaporation rate, seepage rate, and water temperature. The chemistry of pond water has dramatic effects on the pond ecosystem, as well as the organisms being cultured. It also is an indicator of management methods and their success. While a very large number of variables can be monitored, those most commonly related to production in a pond include dissolved oxygen, phosphorus, various forms of nitrogen, pH, alkalinity, and dissolved and suspended solids. Besides the biomass and production of the target organisms in a pond, other biological characteristics are important. Generally, the interest would be in the amount of phytoplankton production in ponds, either by estimating the rate of primary production or the phytoplankton standing crop. While bacteria and other microbes may be very important in pond culture, they are not regularly measured microbial processes in pond waters.

This pond characterization experiment has two goals: the first is to evaluate ponds in Nepal for their physical, chemical, and biological characteristics during a grow-out; and the second is to evaluate production characteristics of Nile tilapia (*Oreochromis niloticus*) in these ponds. The methods for pond characterization are well described in a number of publications, including Egna et al. (1987) and the *Standard Methods for the Examination of Water and Wastewater* (multiple versions of this are available; the most recent is APHA et al., 2012). The purpose of this experimental pond assessment is to describe a series of measurements at each experimental site for the AquaFish CRSP and to outline some of the reasons for these measurements.

Objectives:

1. Evaluate ponds in Southern Nepal for their physical, chemical, and biological characteristics during a grow-out.
2. Compare growth, production, and economics of production of tilapia in different treatments.

MATERIALS AND METHODS

Twelve earthen ponds of Institute of Agriculture and Animal Science (IAAS), Chitwan, Nepal, were used for this experiment. Treatment design consisted of 4 control ponds receiving fertilization alone, 4 fully fed ponds with feed applied at 3% bw, and 4 combined ponds with both feed and fertilizer applied, feeding at 1.5% bw. All ponds were drained, cleaned, and limed with 5 kg/ pond. After a week, ponds were filled and fertilized with urea and diammonium phosphate (DAP). All ponds were stocked with sex-reversed Nile tilapia at 2 fish/m^2 a week after fertilization. Fertilizer was also applied each week at 4 kg N and 1 kg P per hectare for fertilization treatments. Locally available feeds were used to feed twice daily in the morning and afternoon. Fish were stocked on 9 February 2013 and the experiment is ongoing. Ponds will be managed for 120 days and then harvested.

The main water quality variables under monitoring in experimental ponds and frequency of those measurements and their metrics are listed in Table 1. Methods for the measurement of each parameter are based on Egna et al. (1987) and APHA et al. (2012).

Table 1. *Physical, chemical, and biological characteristics measured during pond characterization.*

Variable	Daily Frequency	How often	Type of sample
Pond morphometry	-	Once	
Pond depth (cm)	Once	Daily	One
Evaporation (mm)	Once	3 times	One
Seepage (cm)	Once	3 times	One
Temperature (^oC)	Diel measures	3 times	3 depths
Dissolved oxygen (mg/L)	Diel measures	3 times	3 depths
pH	Diel	3 times	3 depths
Total Alkalinity (mg/L)	Diel	3 times	3 depths
Water depth (cm)	Once	Weekly	Whole pond
Temperature (^oC)	Once	Weekly	3 depths
Dissolved oxygen (mg/L)	Once	Weekly at dawn	Composite sample
pH	Once	Weekly	Composite sample
Total Alkalinity (mg/L)	Once	Weekly	Composite sample
Total phosphorus (mg/L)	Once	Weekly	Composite sample
Total Kjeldahl Nitrogen (mg/L)	once	Weekly	Composite sample
Total Ammonium-N	Once	Weekly	Composite sample
NO_3/NO_2 -N	Once	Weekly	Composite sample
Secchi disk depth (cm)	Once	Weekly	Whole pond
Chlorophyll-a (mg/m^3)	Once	Weekly	Composite sample

Data, including yield, growth rate, and survival, were estimated for fish from all treatments, and comparisons were made using ANOVA. Changes in water quality between treatments and over time were tested using ANOVA. In addition to chemical concentrations, diel measurements were used to determine stratification in the ponds and primary productions rates. These were also compared among treatments using ANOVA.

RESULTS

Fish Growth

Fish growth during 42 days in 3 different treatments are presented in Table 2. The first sampling indicated that fertilizer with half feeding (1.5%bw, T3) gave highest growth, followed by full feeding (3%bw, T2), and fertilizer (T1).

Table 2. *Growth of Nile tilapia in different treatments.*

Treatment	Mean stocking wt. (g)	Mean wt. at 42 days (g)
Fertilizer only (T1)	6.1 ± 0.06	31.2 ± 5.7
Full feeding (T2)	6.2 ± 0.06	38.7 ± 5.2
Fertilizer + half feeding (T3)	6.3 ± 0.04	45.5 ± 3.5

Water Quality

Mean physical, chemical, and biological parameters measured weekly in three different treatments are shown in Table 3. The value presented is the mean over four weeks. Fertilized ponds and ponds fertilized with half feeding had higher pH compared to full feeding ponds. Similarly, higher dissolved oxygen, lower Secchi disk, lower alkalinity, higher ammonium, higher soluble reactive phosphorus, and higher nitrite-N were observed in fertilized ponds followed by fertilized and fed ponds and compared to full feeding ponds. Total Kjeldahl nitrogen increased in full fed and fertilized with feed ponds compared to only fertilized ponds. Total phosphorus was higher in fertilized and fertilized and fed ponds compared to full fed ponds. Chlorophyll-a increased in fertilized and fed ponds compared to the fertilizer alone and only fed treatments. Evaporation measured during this period was 0.3 cm/day.

***Table 3**. Weekly measured physical, chemical, and biological parameters of experimental pond water (Mean of 4 weeks ± SE).*

Parameter	**Fertilized pond (T1)**	**Full feeding pond (T2)**	**Fertilized + half feeding pond (T3)**
Water depth (cm)	79 ± 3.4	78 ± 3.2	82 ± 2.7
Water temperature (^oC)	20.8 ± 0.1	21.4 ± 0.1	21.0 ± 0.1
pH	8.4	7.8	8.2
Dissolved oxygen (mg/L)	9.2 ± 0.8	6.0 ± 0.8	7.6 ± 1.8
Secchi disk (cm)	30.3 ± 4.0	48.1 ± 2.8	37.5± 3.4
Total Alkalinity (mg/L $CaCO_3$)	110 ± 4	124 ± 15	117 ± 9
Total Ammonium-N (mg/L)	0.68 ± 0.03	0.40 ± 0.02	0.58 ± 0.02
Soluble reactive phosphorus (mg/L)	0.33 ± 0.04	0.15± 0.02	0.28 ± 0.02
Nitrite-N (mg/L)	0.04 ± 0.01	0.00 ± 0.00	0.03 ± 0.01
Total Kjeldahl nitrogen (mg/L)	2.66 ± 0.07	2.92 ± 0.12	3.01 ± 0.33
Total phosphorus (mg/L)	1.32 ± 0.20	0.94 ± 0.29	1.12 ± 0.19
Chlorophyll-a (mg/L)	95.6 ± 11.5	26.1 ± 4.8	119.7 ± 33.0

Mean diel water temperature and dissolved oxygen pattern are presented in Tables 4 and 5. These data indicate typical patterns of stratification in the afternoon and mixing in early morning.

***Table 4.** Mean diel water temperature (^oC) measured in 3 depths.*

Treatment	Depth	6 am	10 am	2 pm	6 pm	10 pm	2 am	6 am
T1	15 cm	19.6	24.9	28.9	26.9	24.0	22.4	20.6
	30 cm	19.7	24.5	27.9	26.2	24.0	22.3	20.7
	60 cm	19.7	24.3	26.0	23.9	24.0	22.4	20.7
T2	15 cm	20.4	25.3	29.4	26.9	24.6	23.3	21.5
	30 cm	20.4	25.2	27.7	26.8	24.9	23.6	21.6
	60 cm	20.4	25.0	26.0	25.6	24.8	23.3	21.6
T3	15 cm	19.7	25.5	29.3	26.9	23.8	22.3	21.2
	30 cm	20.0	25.0	27.3	26.1	24.0	22.5	21.3
	60 cm	19.9	24.6	24.5	23.9	22.5	22.0	21.3

Table 5. *Mean diel water dissolved oxygen (mg/L) measured in 3 depths.*

Treatment	Depth	6 pm	10 pm	2 am	6 am	10 am	2 pm	6 pm
T1	15 cm	22.7	9.1	10.9	9.6	11.3	17.4	19.6
	30 cm	7.1	8.9	3.1	8.4	9.0	8.6	11.7
	60 cm	6.5	9.3	2.8	6.7	6.0	5.3	9.3
T2	15 cm	13.5	8.7	7.9	7.6	8.9	13.3	12.5
	30 cm	11.8	9.0	7.6	7.6	7.7	10.5	11.6
	60 cm	8.2	7.3	5.3	7.1	7.7	10.3	8.8
T3	15 cm	21.4	12.9	8.8	9.3	11.2	12.6	16.0
	30 cm	10.4	7.0	7.6	8.5	6.5	11.7	15.4
	60 cm	3.2	5.0	3.5	8.4	3.6	7.2	9.0

DISCUSSION

The experimental ponds were constructed in lowland with high ground water level. Water level increases during the rainy season and decreases in dry season. Results presented are preliminary of four weeks. Stocked fish were sampled only once. Fish growth during this period was highest in fertilized and fed ponds, followed by fed ponds, then only fertilized ponds. Water quality was best in fertilized ponds, followed by fertilized and fed ponds, and then fed ponds. At this point, it appears that ponds with fertilizer and feed had the highest growth and intermediate water quality compared to the other treatments, and most likely the highest economic returns because the inputs were reduced considerably while growth and yield were probably highest.

As this experiment is ongoing, analysis of the data is incomplete. After the completion of the experiment, statistical analysis will be performed.

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TOPIC AREA:
INDIGENOUS SPECIES DEVELOPMENT

❖

DEVELOPING FEEDS FOR LARVAL DORMITATOR LATIFRONS (CHAME)

Indigenous Species Development/Experiment/09IND10UH

FINAL INVESTIGATION REPORT

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ABSTRACT

Chame (*Dormitator latifrons*) is a fish species with significant aquaculture potential. In Ecuador, there have been many years of commercial aquaculture and in México; producers have the expectation to include it as a viable option to produce fish, along with several marine fish species, due to sanitary problems with shrimp culture. In both countries, particularly in Ecuador, upscaling to larger scale commercial aquaculture depends on the achievement of laboratory juvenile production. As to this moment all reported aquaculture in Ecuador relies solely on wild fish. For the last three years our research team has accomplished several objectives regarding the controlled reproduction in captivity of both wild and in-lab adult fish. Other advances have been made in determining best fertilization and incubation conditions. Secondly, many larval rearing trials have been conducted, using both live and dry feeds, but given chame´s morphological features at hatching, significantly small zooplankton and dry feed particles are required. For the present work plan, we focused on the identification of a suitable live prey by isolation, identification and culture from natural environments; to be used either as only food source or in combination with dry feeds, as well as a few trials of pond rearing conditions. Our results identified some specific rotifer genus, which comply with a lorica length under 90 microns (chame´s mouth gap size), and are present at different salinities (*Proales* and *Proalides* sp. to mention a few); several feeding trials either using *Proalides* as single food source (with or without bioenrichment) along with dry feeds were carried out. Although no survival was observed beyond 6-7 days post hatching, significant consumption of offered rotifers was observed. Also, a shrimp and artificial pond rearing trials were conducted, with similar results with regards to survival. As final conclusions, there is still an initial signal, given by food type or composition missing on the tested feeding protocols, to ensure enzymatic activity and therefore chame larval survival, once exogenous feeding starts.

INTRODUCTION

One of the main limiting factors for fish larval rearing is to offer a suitable zooplanktonic prey that contains all the needed nutrients for a particular species, being among the most important amino acids and fatty acids (Garcia-Ortega et al., 2003). Rotifers are an important source of live feed for larviculture. However, most commonly used species have not been appropriate for many fish, due to their body size when compared to fish larvae mouth gap (Wullur et al., 2011). Thus, research focused on live feed massive production is essential for fish commercial production at several levels. Diversification of aquaculture relies on the controlled propagation of a particular species of interest. For fish, larvae exhibit many particularities especially at the early ontogeny stages, when focusing on the physiological ability to start exogenous feeding, as previously described for chame (Rodriguez M de O et al., 2012). Many approaches to offer a suitable pray or feed are described in the literature; a particular emphasis is made on the composition and proximal quantity and quality to guaranty a significant amount of both protein and fatty acids by means of zooplankton bioenrichment techniques (Garrido et al., 2013). Also, the utilization of both pre and probiotics are described as a relevant factor to ensure, maturation of digestive tract using bacteria as initial feed or as a contribution to intestinal flora for supplemental enzymatic activity in larval gut (Zink et al., 2013). Nevertheless, both aspects are of more significance as to increase survival rates once larval rearing has taken place (Lihnsteiner et al., 2012), as well as to reduce the time for weaning to dry diets (García-Ortega, 2009). Other approaches include the co-feeding of both dry and live feeds, the later obtained from sources such as mesocosm (Cunha et al., 2013), biofloc (Wilson, 2012), and broodstock rearing tanks, among others.

From our previous work, we have identified two major constrains to achieve chame larval rearing. The first key aspect is related to the identification of a suitable prey of chame larvae due to its small mouth gap (approximately 90 microns), as previously used rotifer strains with lorica size above 120-150 microns are too large for ingestion (Rodriguez et al., 2012). Second, we must identify the initial factor or factors for optimal composition or type of initial feed, either alone or in combination (mixed feeding). Also the possibility to offer a wider variety of potential food sources either as phyto- or zooplankton by means of pond rearing (Ludwic, 1999), that potentially offers a significant diversity of organisms in a similar way to chame natural environments; where salinity might play a major role as described by McDowall (2009) given chame´s amphidromy conditions as part of its life cycle.

Therefore, we focused on the identification, isolation and culture of microzooplankton (smaller than 100 microns) from several locations within a 150 km radius of Mazatlán Sin., where chame juveniles have been gathered for the last 4 years, after collection of sediment from these locations. Also, such sediment is a reservoir of other many planktonic resting stages, therefore suitable to recreate natural conditions in a pond; offering an alternative technique for fish larval rearing. Following Ludwig (1999) recommendations for fish larvae pond rearing, in a tank in a research facility, rotifers encysted in the soil will hatch in the tanks and feed on the various phytoplankton blooming from previous fertilization. Unlike most marine larviculture practices where axenic zooplankton cultures are used, we will purposefully culture numerous rotifer species simultaneously to simulate the successful strategies used in pond culture situations. For the later, salinity is a key element to obtain a wider diversity of organisms from these sediments; hence, the effect of several salinities (10, 15, 20 and 25 ppt) on the abundance and specific composition of emerging rotifers from resting eggs found on pond sediment was investigated, showing a significant effect on specific composition and rotifer abundance. Resting eggs from observed species were produced after initial culture, and cyst production was achieved and subsequently stored using synthetic sponges for later use as initial inoculation for massive rotifer production. Such generated information was used according to the originally proposed research objectives as follows:

1. Artificial pond rearing of chame larvae
2. Use of microzooplankton (<50 microns) as initial feed
3. Use of highly digestible artificial microdiets
4. Mixed feeding programs

MATERIAL AND METHODS

Chame Broodstock

3,000 Chame juveniles (1-4 g individual weight) were collected in Hacienda el Tamarindo, Rosario Sinaloa (23°01´57´´N; 105°48´26" W) during Sep-Nov 2012. Later on Dec 2012, fish were placed in twelve 2m^3 polyethylene plastic tanks previously used for tilapia/pangasius biofloc culture, using the biofloc as natural food for overwintering purposes, until March 2013. A second set of 250 chame adults (15 cm minimal length) were collected at the commercial shrimp farm "Acuícola San Jorge" (23°09´10.54´´N; 106°18´22.84" W) in early September 2013. Later on, chame from the first lot were transferred to 9m^3 elevated plastic liner tanks, to complete grow-out and gonad maturation. Potential breeders from both groups were monitored starting mid-September for maturity and pre-selected for hormonal induction.

Larvae production

Sexually mature chame broodstock were managed according to pre-established hormone application procedures outlined in Rodriguez M de O *et al*, (2012). Females were induced using a single implant of 75 µg LHRHa (Ovaplant, Syndel®) and males were injected a single 40 µg/kg LHRHa dosage. A modification on female spawning was carried out for females towards the end of the reproductive season (Mid October-Late November) with 3 consecutive 100-150 µg/kg LHRHa intramuscular injections, with a 20-35% success rate in 5-8 fish groups.
Once both males and females released gametes, artificial fertilization was performed at 0 ppt salinity, using UV sterilized water, previously filtered to 5 µm and with activated charcoal. Oocytes were placed at a ratio of 5 g of spawn (80,000 cell/g proximately) with 1-3 ml of sperm from 2-4 males per liter. Fertilization was carried out for 3-4 minutes and eggs were washed twice with clean water. Thereafter, eggs were placed in McDonald jars with significant aeration for 14-18 hours until all viable eggs hatched. Larvae were transferred to holding tanks at 0 ppt, counted and distributed into experimental rearing tanks.

Pond rearing of chame larvae

Natural pond. A shrimp pond (0.3 ha) located in Estación Dimas, San Ignacio Sinaloa México (23°42´57´´N, 106°48´58´´O) was facilitated by Mr. Fernando Osuna Palacios. For preparation, 30 kg/Ha was added for 7 days to the pond, and previously filled with water at 15 ppt salinity, passed through a 250 micron screen. Later on, 75,000 (2 dph) chame larvae were stocked and monitored after 10 days to evaluate larvae survival (Fig. 1).

Outdoor artificial ponds. Two 2m^3 polyethylene plastic tanks were setup at FACIMAR-UAS for a similar larval rearing trials (Fig. 2). Each tank was prepared at two different salinities, 0 and 15 ppt, using both fresh water and salt water screened with a 100 bag filter and fertilized continuously for 12 days with a mixture of wheat bran, urea and phosphoric acid. Each pond was stocked with 3 kg of sediment from specific locations, later on 18,000 larvae were stocked within 5 days after tank setup. Water quality as pH, DO and T° were monitored daily. Several rotifer monitoring surveys were performed during a 15 day period.

Laboratory artificial pond (Experiment 1). Sponges impregnated with rotifers cysts produced from previous trials (see procedure below), were placed in 21 clear polyethylene plastic tanks (20 l total volume) prepared at different salinities (0, 4, 12, 19, 28, 35 ppt) with three replicates per salinity, using both UV sterilized filtered water to adjust salinity. Each tank was fertilized with urea, wheat bran and phosphoric acid (1.6, 20 and 0.6 ppm respectively) (Fig. 3) and subjected to 24 light cycle, two sponges about 10x10x8 cm were stocked on each replicate. Tanks were monitored for rotifer emerging within 5 days after initiation, for later adding of 100/l chame larvae 1 dph. Thereafter, 2 ml of RotiGrow® were added daily to each tank.

Production of micro rotifers (<50-100 microns) as initial feed

Wild rotifers were produced using the same procedure as described above for artificial ponds. In specific, collected as latency stages from soil samples originated from different locations. Organisms from the Brachionus genus and other brackish and saline environments were produced from sediments collected at the commercial fish farm "Acuicola San Jorge" located nearby the Mazatlán international airport (23°09´10.54´´N; 106°18´22.84" W) directly from several ponds an used to inoculate tanks at 10, 15, 20 and 25 ppt salinity. Rotifer diversity was monitored for over 20 days at each salinity. Rotifers produced from these soil samples were induced to produce cysts, by placing 3-5 liters from production tanks in clear plastic boxes with the addition of synthetic polyurethane sponges, directly exposed to sunlight to allow water evaporation (Fig. 4).

Fresh water and other low salinity inhabitant rotifers were obtained from sediments collected in several temporary water reservoirs at the Rincon del Verde, Escuinapa Sinaloa community, 80 km south of Mazatlán (22°53'44.07"N, 105°48'57.47"W). For these rotifers, tanks were setup and the desired rotifers (less than 100 microns) only appeared once the rain season started, after 45 days of initial inoculation. Among the observed microrotifers was the genus *Proalides* sp.; this particular rotifer was selected due to its morphological characteristic (@50-70 microns lorica length, Fig. 5). Several attempts were carried out for massive culture of one of the identified and isolated rotifers using artificial feeds such Rotigrow®, Algamac®, commercial baker´s yeast and live microalgae (*Chlorella* and *Scenedesmus* sp) without success. Thus, as an alternative, given that this rotifer was present at very high concentrations in the chame broodstock holding tanks, green water was transferred to other set of tanks and used as production units, concentrating present rotifers using 55, 35 and 11 μm sieves prior to larval feeding trial.

Mixed feeding schedules evaluation.
According to the originally proposed activities on the present work plan, several experiments were conducted (Fig. 6), using as starting point the micro rotifers produced as described above in combination with the following inert diets and other elements:

- Algamac 3000 (Aquafauna Bio Marine®) **(A)**
- Algamac protein plus (Aquafauna Bio Marine®)
- *RotiGrow*® (Reed Mariculture Inc) **(R)**
- Centrifugated fractions of Rotigrow® **(RC)**
- Green water[a]. **(GW)**
- Probiotic mix[b]. **(Pro-M)**
- Epicin G2 **(P1).**
- Epicin Hatcheries **(P2).**
- Protein HUFA rotifer enrichment product (Salt Creek®) **(PH)**
- Herbal Tea[c] **(Tea)**
- Molasses **(M)**
- Epilite Z (70 micron liquid microparticulated diet) (Epicore BioNetworks Inc.)
- Forze Vit forte[d] **(Vit mix).**

[a]Green water: mixture 1:1 of 55 micron sieved water from Chame broodstock rearing tanks plus tilapia biofloc water supplemented with molasses as carbon source.

[b]Probiotic Mix: 5 g of Epicin G2, Epicin Hatcheries and Epicin 3W (Epicore BioNetworks Inc.) was prepared. 0.2 g were dissolved in 100 ml filtered water and 1 g of molasses was incorporated prior to addition to larval rearing tanks.

[c]Herbal tea: Infusion Kundalini® *(Althaea officinalis, Crataegus pubescens, Cocolmeca smilax, Matricaria recutita*).
[d]Forze Vit forted infant vitamin and mineral supplement (Bee royal jelly, PUFA´s, glutamic acid, B vitamin complex, L-lysine).

Experiment 2: As an initial trial for the rotifer *Proalides*, either as a single feed or in combination with the above-mentioned inert diets. 100 chame larvae were stocked in 1 liter containers previously filled with UV sterilized 5 µm filtered fresh water, and assigned to 7 experimental treatments, with three replicates each, as follows (Fig. 1): No food as control (CON), green water (200 ml)+protein Hufa 1 ppm+rotifer (GW/PH/R), centrifuged Rotigrow+rotifers (RC/R), rotifer (R), green water+epicin G2+molasses+rotifer (GW/P1/M/R), green water+epicin hatcheries+molasses+rotifer (GW/P2/M/R) and green water+rotifers (GW/R), with 15% water exchange rate on a daily basis, rotifers were added in corresponding treatments at a daily ratio of 3 org/ml. Simultaneously, the same experimental treatment layout was carried out, including a 1 ppt salinity increment per day as part of the 15% water exchange procedure. Daily rotifer counts and larvae presence per container were conducted.

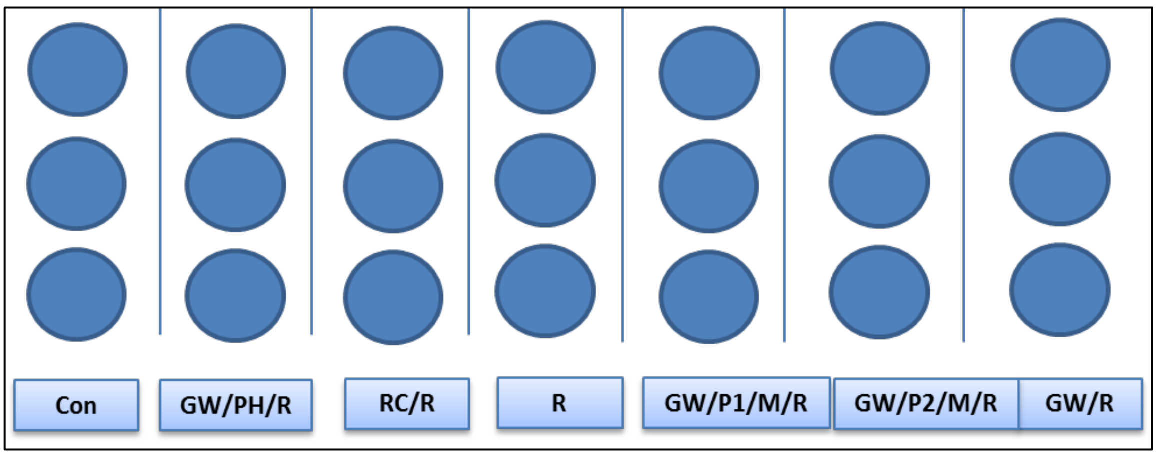

Figure 1. *Treatment layout for experiment 2.*

Experiment 3: Following Cunha et al. (2013) and Wilson (2012) procedures that combined different live food sources such as green water or biofloc in combination with bioenriched rotifers, this experiment was performed considering all these factors, along with the inclusion of a waterborne source of enzymatic co-factors (vitamin mixture) and the addition of a probiotic source in the water. Four major treatments with different levels, either as presence or absence of green water (mesocosm) and bioenriched rotifers with one of two different products were outlined (Fig. 2). Such treatments correspond to the following arrangement: A: Algamac 3000; A/P: algamac 3000 + probiotic mix; A/P-M: algamac 3000 + probiotic mix + molasses and P-M: probiotic mix + molasses. All products were added twice to rearing containers (10 L clear plastic containers with constant aeration) using manufacturer´s guidelines and rotifers were added daily after 1 hour of bioenrichment with either Algamac Protein Plus or Protein HUFA, at a minimum of 10-11 rotifers per ml, at 3 dph of larvae and counted daily, until larvae were no longer observable. Prior to initiation of feeding, 250 2 dph larvae were stocked at an initial volume of 2 L of UV sterilized 5 µm filtered fresh water; for green water tanks, 250 ml of green water were added to complete 2 L. Total container volume was increased on a daily basis with either 250 ml of fresh water or green water as corresponding from experimental layout (Fig. 2). As additional management, 4 tanks per treatment were supplemented with 0.15 ml of liquid vitamin mix.

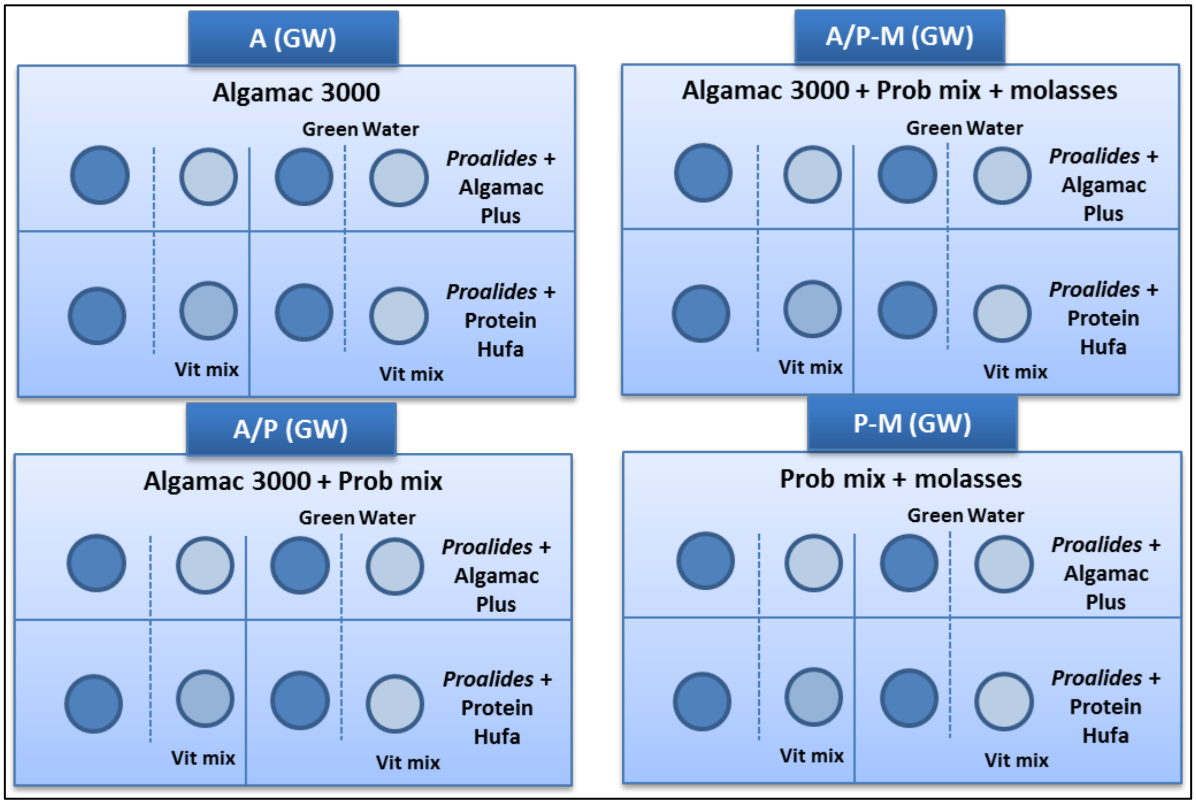

Figure 2*. Experimental treatments layout for experiment 3.*

Experiment 4: A higher density enriched rotifer feeding trial was carried out, once again, in combination of either green water, probiotics, molasses and a bag of a commercially available herbal tea (as potential sources of feeding stimulants and/or other factors) according to the layout described in the following diagram (Fig. 3). 20 L clear plastic tanks with constant aeration were filled with either 5 L of UV sterilized 5 um filtered fresh water or 35 um sieved green water, were stocked with 250 larvae/L. Bioenriched rotifers (Algamac Protein Plus) were added daily, twice a day, days 3 and 4 dph at 4 (am) and 8 (pm) rotifers per ml, and from day 5 dph adding numbers were 10 (am) and 20 (pm) rotifers per ml, respectively at morning (9 am) and afternoon (pm), probiotic mix and/or molasses were added daily. Tanks volume was increased daily adding 2 L of water, in a 1:1 ration fresh water (FW)/salt water (SW). FW was added directly to tanks and SW was added by constant dripping to rearing tanks. Rotifers were counted daily in the morning, until larvae were no longer visible.

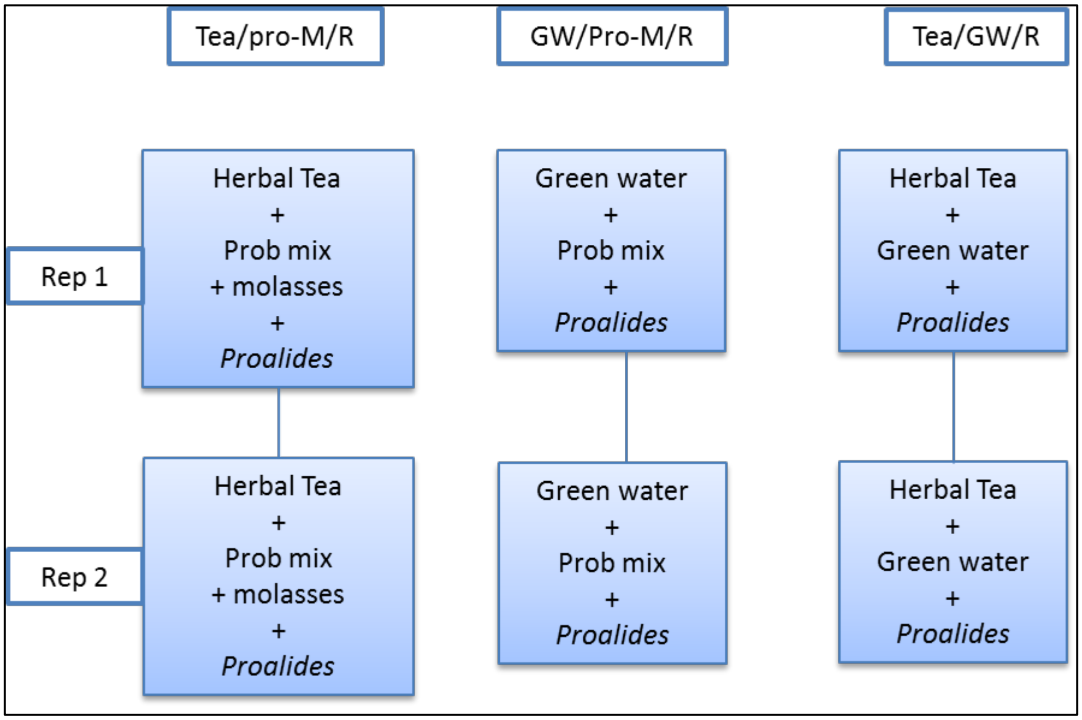

Figure 3. *Experimental treatments layout for experiment 3.*

Extra activities: Identification and isolation of potentially probiotic bacteria from juvenile chame intestinal tract.
Chame juveniles (49.8±0.1 g) were dissected for full digestive tract removal, placed in sterile saline solution and shipped to the Faculty of Medicine of the Universidad Autónoma del Estado de Morelos (UAEM, Cuernavaca Morelos) for isolation and culture of probiotic bacteria. Intestinal segments were homogenized and consecutive dilutions in 0.89% saline solution were conducted and incubated in MRS Agar (each dilution). Samples were incubated for 24h at 37±2 °C. Each plated was counted for colony forming units, and positive dilutions were used for reseeding; thereafter, positive plate bacteria were used for catalase and gram staining for further identification. Probiotic activity was measured by means of bile salts tolerance at different pH values and API CHL and API 50 CH biochemical tests were carried out for taxonomical identification.

RESULTS

Pond rearing trial: No presence of post-larval fish was observed after 10 days, when final observations took place. Water samples (15 ppt salinity 30.5°C temperature, secchi depth 22 cm) were taken for microscopic observation to FACIMAR-UAS at moment of stocking and 3 days later, showing a significant number of copepod nauplii, copepodits and larger stages, diatoms and large *Brachionus* sp. rotifers at the moment of larvae seeding in pond, A significant number of mussels invaded the pond by day 6, removing most of primary productivity by day 8-9, resulting in transparent water; although pond was fertilized two more times (Nutrilake) and extra water added to avoid a sudden increment of salinity at days 4 and 8.

Artificial pond trial: For the outdoor tank, daily observation of 11 water samples indicated that larvae were still present at 5 dph at low salinity (0 ppt), whereas live larvae were observed only until 3-4 dph at 15 ppt. Low salinity tanks, in all cases, reached lower secchi values sooner (3-5) days at 26-30°C than higher salinity tanks. Predominant phytoplankton was different as color of rearing water, with a high presence of both *Chlorella* and *Scenedesmus* sp.; being diatoms such as *Chaetoceros* sp among others free living microalgae. A relevant observation was made with regards to rotifer species' natural succession in the artificial ponds, given those smaller rotifers, either fresh water (*Proalides*) or brackish water (*Proales*) can be observed only when larger organisms (rotifers) are no longer present at high counts in the tanks. Therefore, blooming tanks might not offer the desired small rotifer composition and density, appropriate for chame larvae rearing. Other pertinent observations made, indicate some degree of synergy between the presence of specific types of microalgae, as *Proales* eggs adhere to an unidentified filamentous algae, and *Proalides* apparently consume another colony forming algae (*Eudorina*-like sp). This algae can be extensively found in broodstock holding tanks and be eventually used its culture.

For the indoor (laboratory) artificial ponds; although no segregation by species was made for daily counts, observed rotifers were high within 6 days after initial inoculation with sponges and daily fertilization; particularly for brackish salinities (between 10-20 ppt) as described in table xx, being as high as 100 rotifers per ml (Table 1). Although fertilization was discontinued when larvae were placed in experimental tanks, Rotimac® was used as supplemental feed for both rotifers and larvae. Larvae were no longer visible in tanks within 5 days after stocking, despite high rotifer counts, in a similar fashion to both natural and artificial pond rearing trials (Fig. 15).

<u>Production of micro-rotifers</u>: Further trials to taxonomical and morphologically identify emerging rotifer species and the effect of incubation salinity of collected sediment was conducted. Among the main rotifer genus identified at salinities above 10 ppt were *Brachionus, Lecane, Proales,* and *Colurella* (Fig. 10) being the last three rotifers with many desired characteristics for further utilization as initial live feed for fish larviculture; in particular, *Proales* and *Colurella* showing sizes under 90±20µm (Fig. 11). Rotifer counts revealed significant differences in specific diversity in relation to water salinity and time after inoculation (Fig. 12). For fresh water trials, main genus' included *Filina* and *Proalides* as well as small size *Brachionus angularis* with similar size characteristics (Fig. 11).

<u>Mixed feeding trials</u>: As mentioned, many feeding trials were carried out. Survival did not improve in number of days until larvae were no longer visible in rearing vessels, as in past rearing seasons larvae did survive until 7 days. Although other variables are being studied to validate the magnitude of the effect of actual rotifer consumption as observed on larvae fed with *Proalides* (Fig. 13), such as modified Fulton´s condition index still under analysis, we observed different survival values as total days among the executed experiments (Fig. 14). At first glance, we observed a longer life span on larvae feed on a mixed food regime (Exp, 2, 3 and 4) as overall number of days stretched to at least 6 days, than on the in-lab artificial pond trial. Also, we observed different life durations within experiment for trials 2, 3 and 4 (Fig. 16 and 17), where probiotic, to rearing water either as a single type or in a mixture addition, allowed to observed larvae presence for 1-2 extra days (Fig 16 and 17). The use of an Herbal tea on rearing water also increased larval life span as no differences were observed between trails (Fig. 18).

An interesting finding was the actual reduction values of rotifer density per experimental unit, providing an idea of an apparent consumption of the *Proalides* rotifer by chame larvae (Table 2, 3, 4 and 5). At this moment, with still pending digital analysis of chame larvae to establish potential condition index differences both between experiments and within treatments, the favorable ingestion of this rotifer provides relevant information on finally finding a suitable prey for chame larvae for low salinity trails, and further research using *Proales* at higher salinity conditions.

<u>Probiotic bacteria identification</u>: Tests conducted on juvenile chame digestive tracts allowed the identification of several gram-positive bacterial strains of the *Lactobacillus* genus and *Lauconostoc*. With mild to high tolerance to bile salts as well as low pH values (3 and 4), with pending results for negative catalase activity evaluation by means of API tests.

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Table 1. *Number of emerging rotifers of several genus observed per salinity treatment in laboratory condition artificial pond trial using sponges as cyst reservoirs (rotifers per ml) after stocking newly hatched chame larvae (experiment 1).*

Salinity (ppt)						
dph	0	4	12	19	28	35
1	2	12	116	72	65	78
2						
3	3	16	102	54	43	66
4	3	25	98	50	49	55

Table 2. *Initial rotifer count in 1 l containers (2 dph) and morning rotifer count in following days (prior to daily stocking 3 rotifers/ml) in experiment 2 at 0 ppt conditions.*

Treatment							
dph	Con	GW/PH/R	RC/R	R	GW/P1/M/R	GW/P2/M/R	GW/R
1							
2		3	3	3	3	3	3
3		3	1	1	1	1	3
4		4	4	4	3	3	4
5			4		5	5	
6							
Rotifers per ml counted the day after feeding.							

Table 3. *Initial rotifer count in 1 l containers (2 dph) and morning rotifer count in following days (prior to daily stocking 3 rotifers/ml) in experiment 2 with salinity gradient (1 ppt increase per day).*

Treatment							
dph	Con	GW/PH/R	RC/R	R	GW/P1/M/R	GW/P2/M/R	GW/R
1							
2							
3		3	3	3	3	3	3
4		5	4	3	2	2	2
5			5	4	2	2	2
6							

Table 4. *Proalides sp. rotifer apparent consumption of chame larvae, describing both observed (O) and added (A) rotifers per day per ml of rearing tank at each treatment within experiment 3.*

Treatment																
dph	A		A/GW		A/P-M		A/P-M/GW		A/P		A/P/GW		P-M		P-M/GW	
	O	A	O	A	O	A	O	A	O	A	O	A	O	A	O	A
1																
2																
3		11		11		11		11		11		11		11		11
4	6	11	8	11	6	11	6	11	6	11	8	11	10	11	8	11
5					8	11	10	11			10	11	10	11		

Table 5. *Proalides sp. rotifer apparent consumption of chame larvae, describing both observed (O) and added (A) rotifers per day per ml of rearing tank at each treatment within experiment 3.*

Treatment						
	Tea/GW/R		Tea/Pro/R		Tea/Pro-M/R	
dph	O (am)	A (am-pm)	O (am)	A (am-pm)	O (am)	A (am-pm)
1						
2		4-8		4-8		4-8
3	2	4-8	3	4-8	2	4-8
4	4	10-20	5	10-20	5	10-20
5	10	10-20	8	10-20	10	10-20
6	12		10		10	

Figure 4. *Location of shrimp farm pond (Estación Dimas Sin. México) and 2 dph chame larvae stocking for pond rearing trial.*

Figure 5. *Artificial ponds for chame larvae rearing trials and wild rotifer production.*

Figure 6. *Organic and inorganic fertilizer used for artificial ponds. A) wheat bran 20 ppm, b) phosphoric acid 0.6 ppm and c) urea 1.6 ppm.*

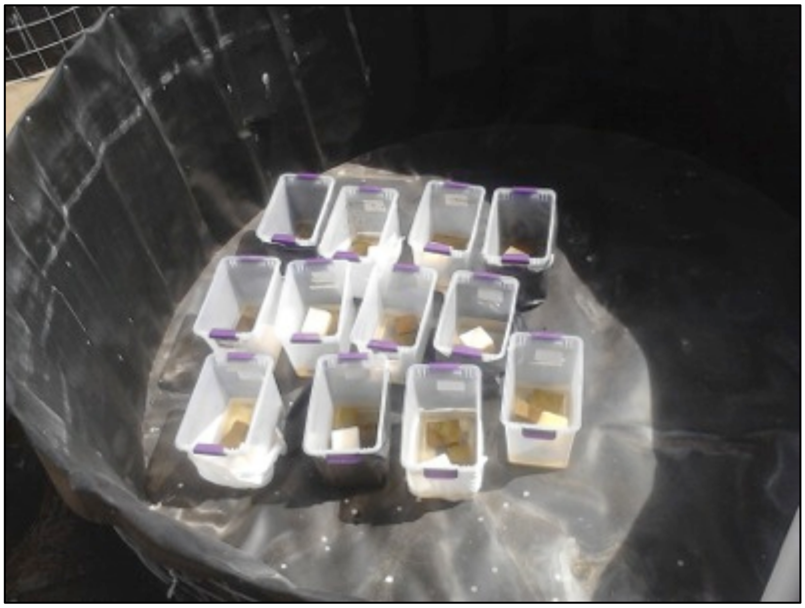

Figure 7. *Rotifer cysts production with collecting sponges.*

Figure 8. *Proalides sp rotifer, produced in fresh water from collected sediments. (Left: in-lab photography 400x magnification; Right: high resolution pic with size bar for demonstrative purposes (source:http://www.plingfactory.de/Science/Atlas/KennkartenTiere/Rotifers/Epiphanidae/im/Liliferotrocha121-8.jpg).*

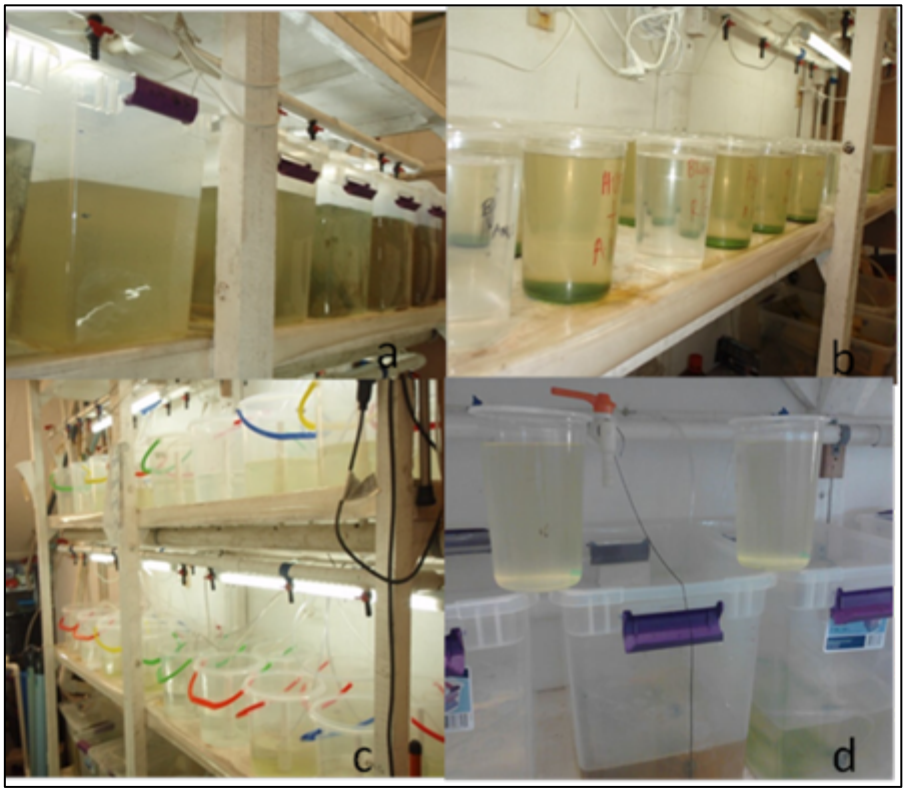

Figure 9. *Mixed feeding experiments tank layout for chame larvae rearing. a) experiment 1, b) experiment 2, c) experiment 3 and d) experiment 4.*

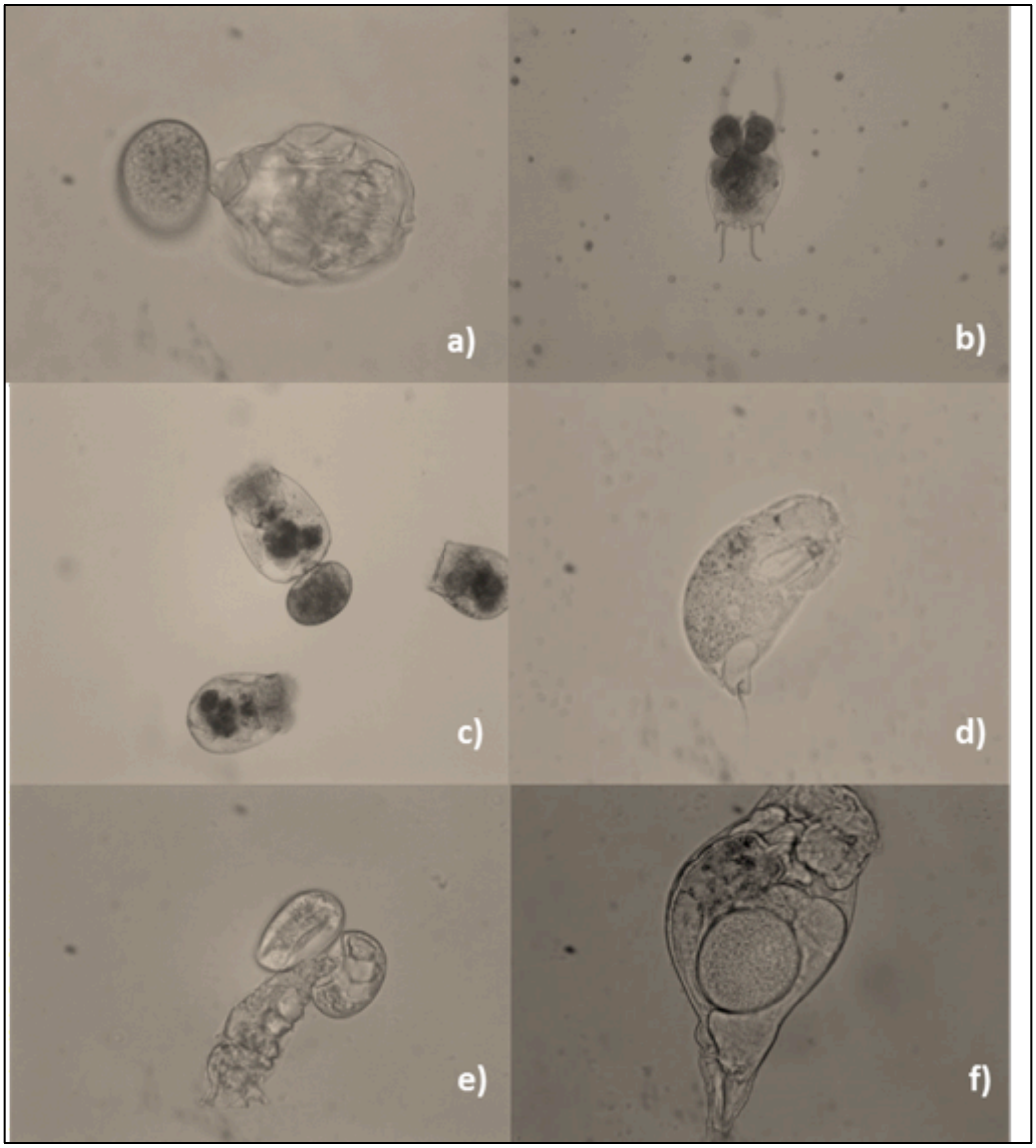

Figure 10. *Sample of wild rotifers produced from artificial ponds at different salinities. a) Brachionus angularis, b) Brachionus falcatus, c) Brachioonus plicatilis, d) Colurella sp., e) Filina longiseta, e) Proalides tentaculus, f) Proales sp.*

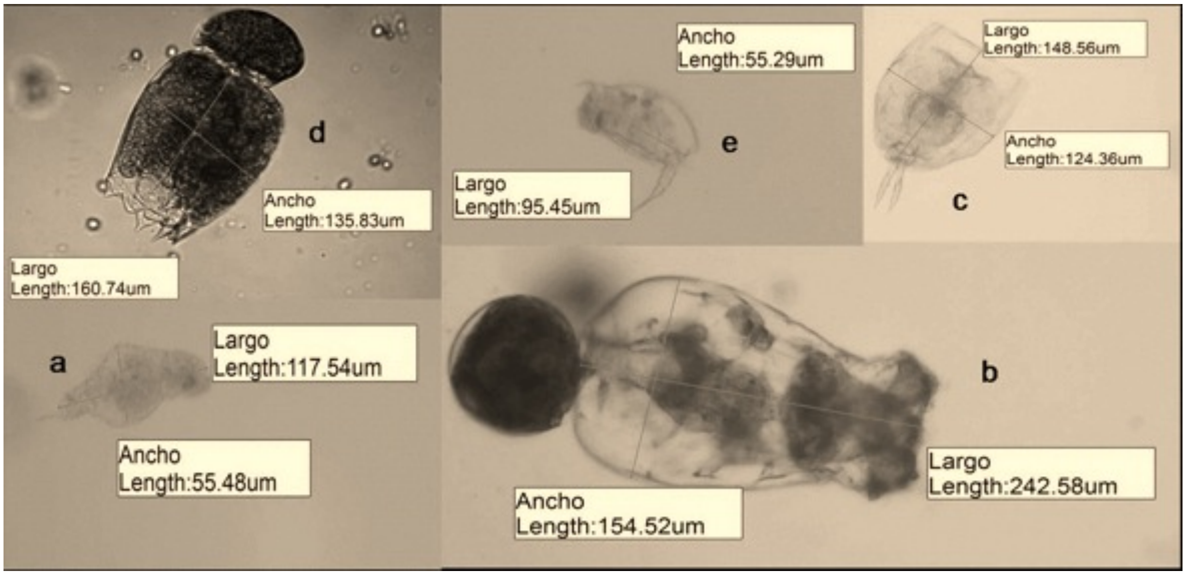

Figure 11. *Morphological characteristics of emerging rotifers produced at different salinities: a) Proales sp., b) y d) Brachionus sp., c) Lecane sp. y e) Colurella sp.*

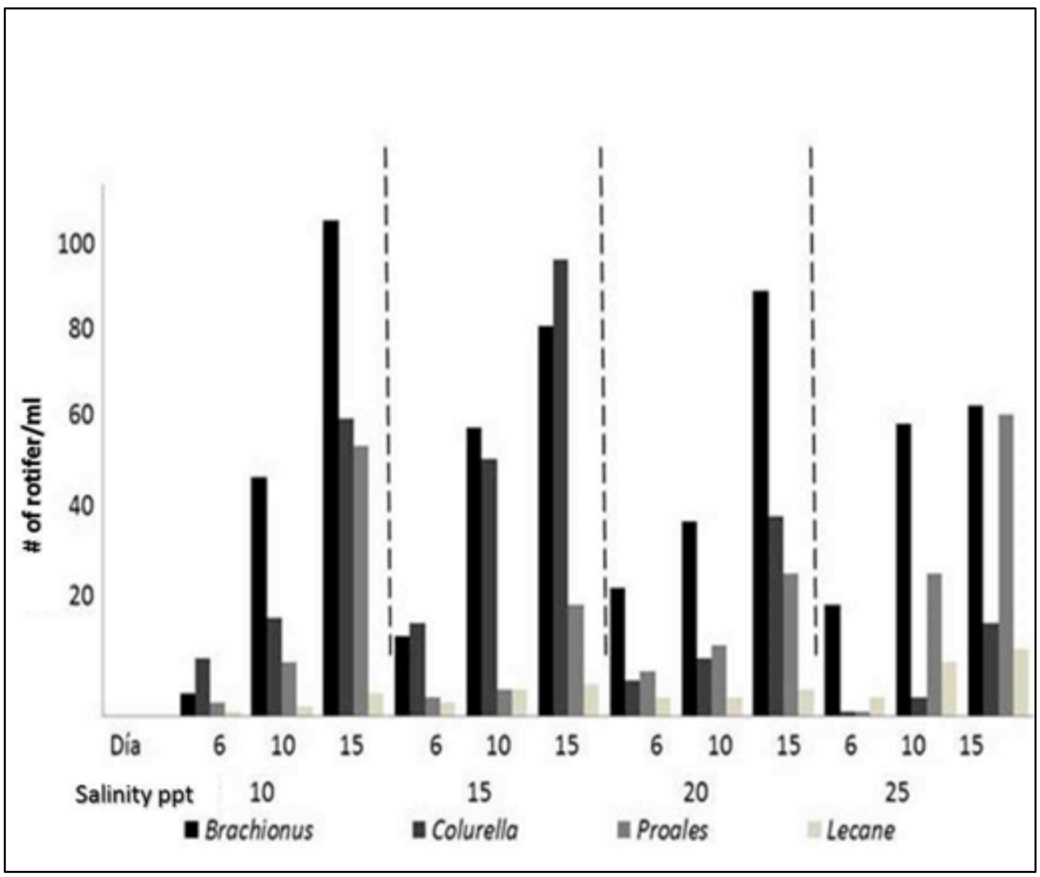

Figure 12. *Specific abundance of emerging rotifers (densities rotifer/ml) at four salinities (10, 15, 20 and 25 ppt) at different times after initial fertilization (6, 10 and 15 days) in artificial ponds using sediments from a commercial shrimp farm.*

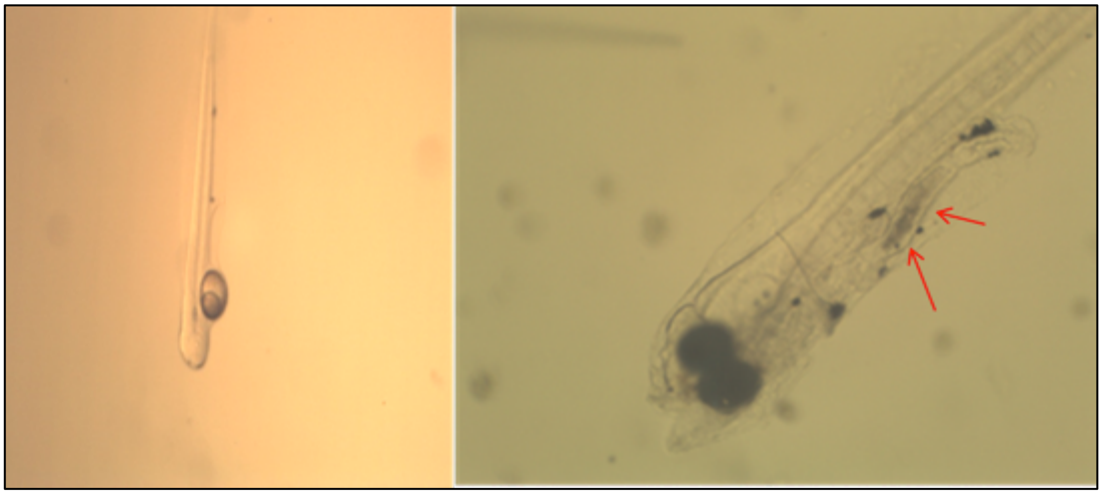

Figure 13. *Newly hatched larvae (left) and 5 dph chame larvae fed with rotifer Proalides and Algamac 3000® (right). Arrow indicates gut content*

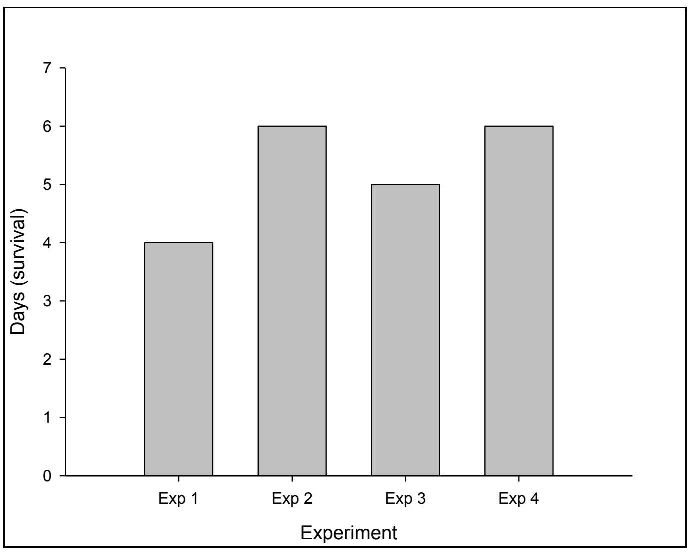

Figure 14. *Overall survival values (days) observed within different chame larvae rearing trials.*

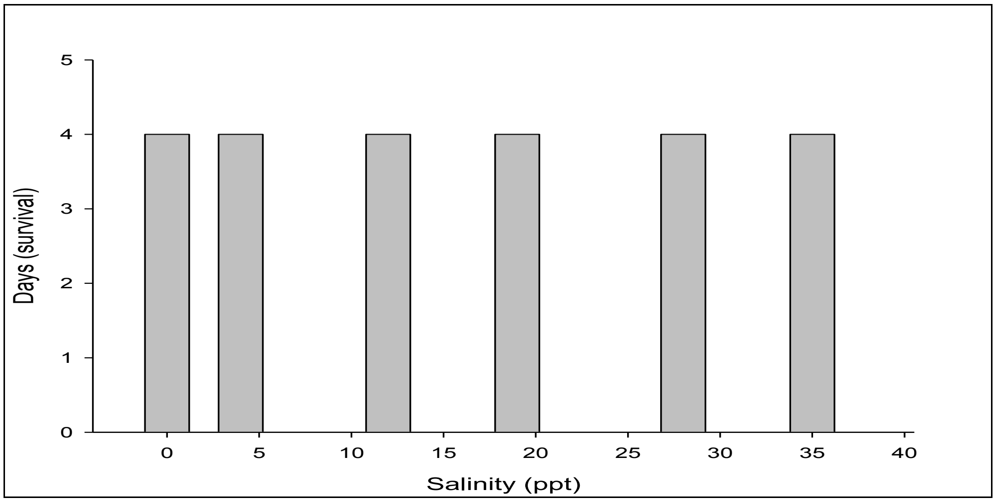

Figure 15. *Overall chame larval survival in days (live larvae presence) in experiment 1, using sponges as rotifer reservoir at different salinities.*

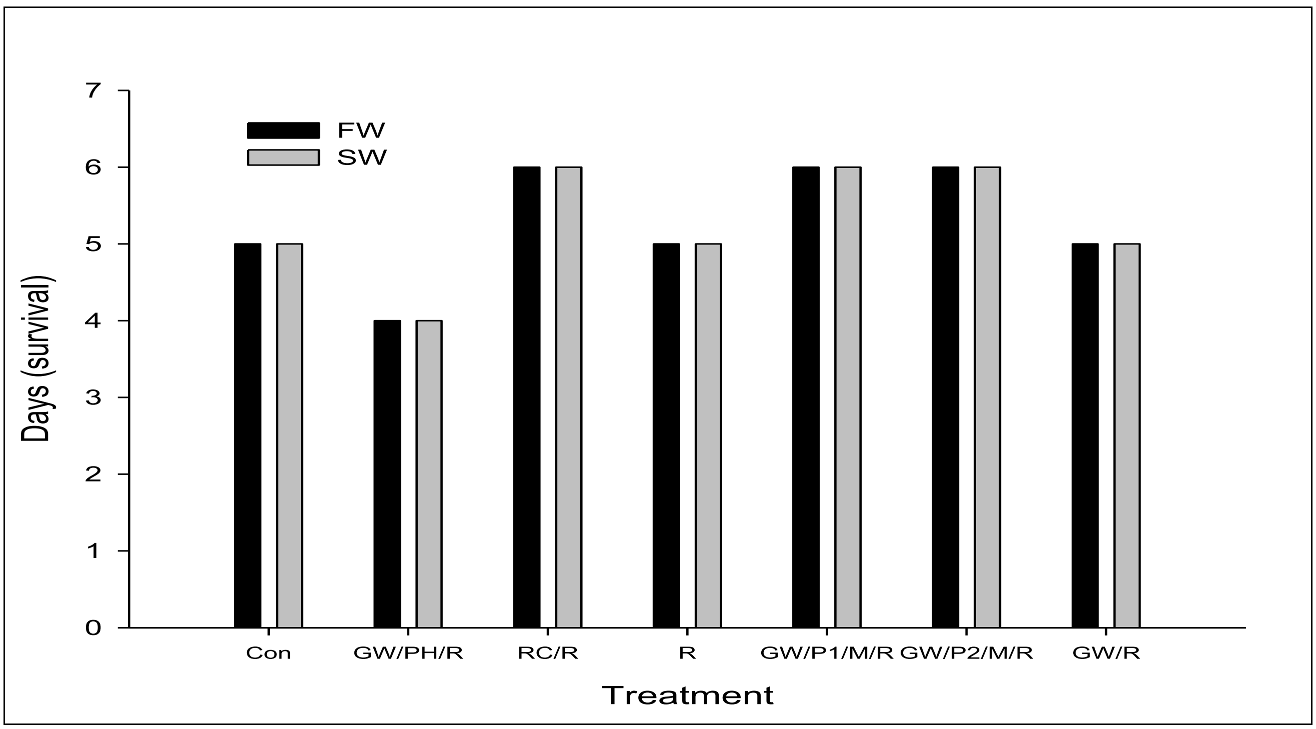

Figure 16. *Overall chame larval survival in days (live larvae presence) during experiment 2, in fresh water (black) or 1 ppt per day salinity increment (gray)*

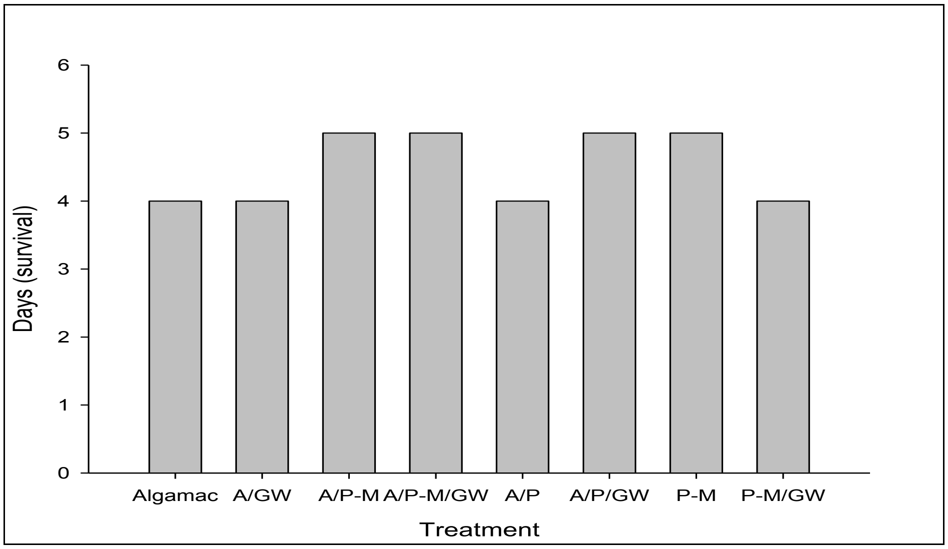

Figure 17. *Overall chame larval survival in days (live larvae observance) in experiment 3.*

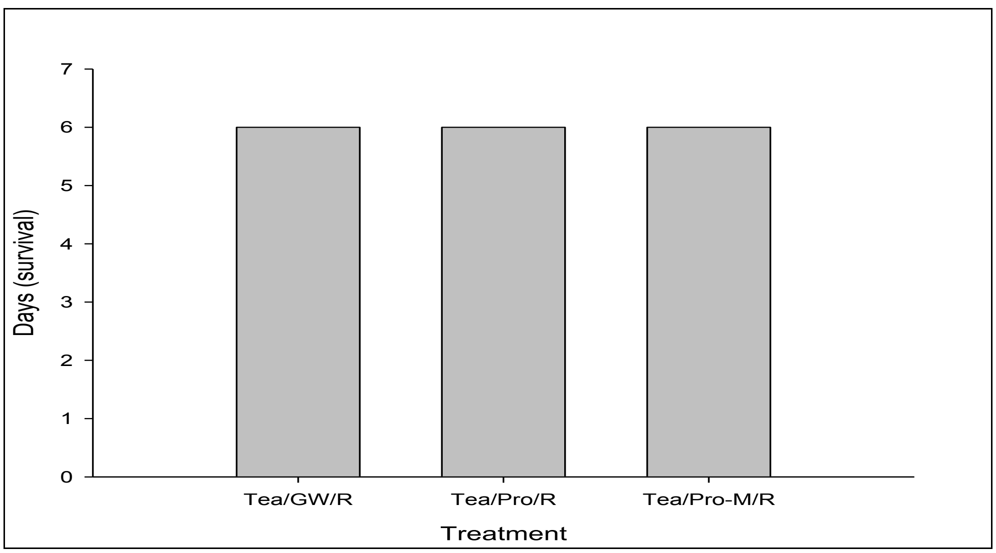

Figure 18. *Overall chame larval survival in days (live larvae observance) in experiment 4.*

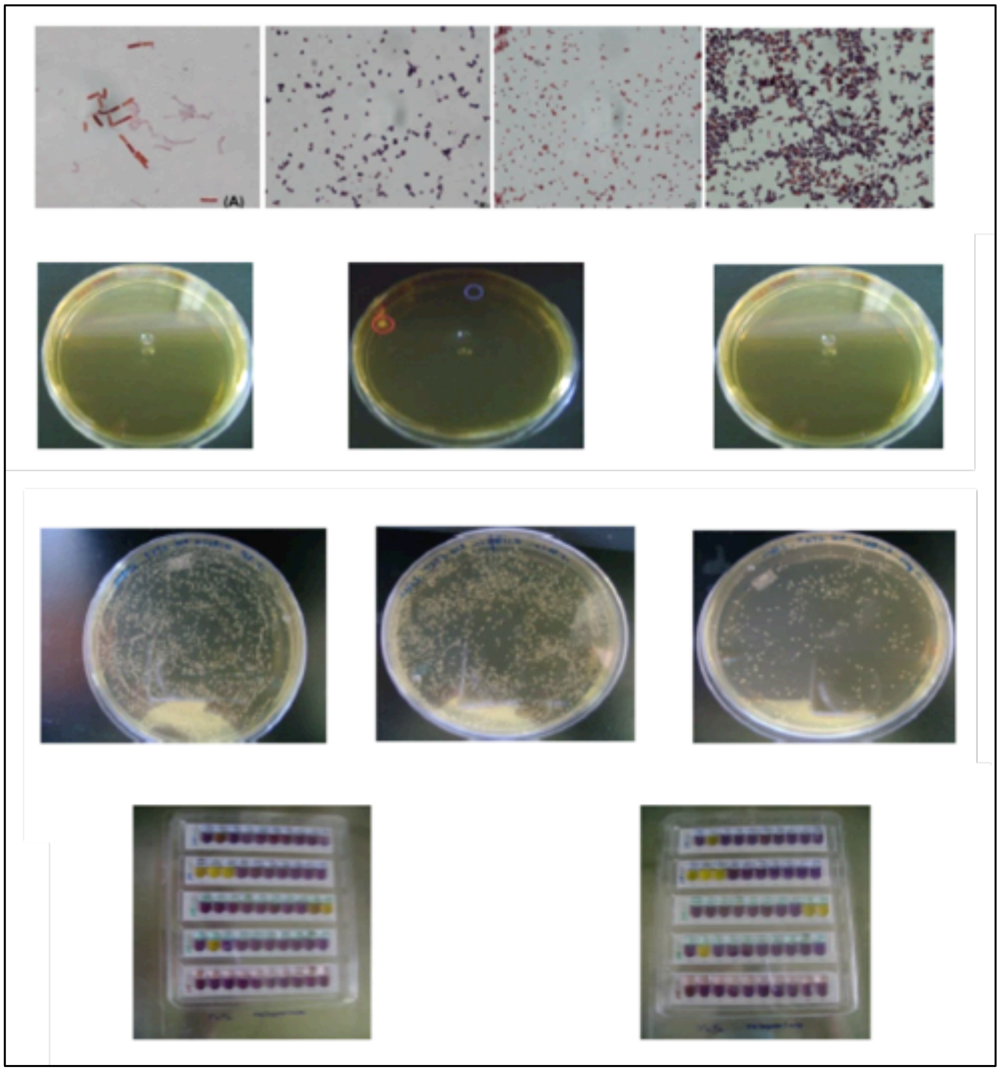

Figure 19. *Probiotic caracterization of isolated bacteria from Chame intestinal tract. From top to bottom: Gram staining, bile salt tolerance, pH resistance and API test for biochemical bacteral identification*

TOPIC AREA:
INDIGENOUS SPECIES DEVELOPMENT

❖

DEVELOPMENT OF SUSTAINABLE FEEDS, IMPROVED STOCKING DENSITIES, AND SALINITY MANAGEMENT IN CLOSED RECIRCULATING SYSTEMS FOR GAR (*ATRACTOSTEUS* SPP.) CULTURE

Indigenous Species Development/Experiment/09IND11UM

FINAL INVESTIGATION REPORT

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ABSTRACT

The purpose of this study was to determine success of closed and recirculating filtration systems on water quality and growth of tropical and Cuban gars, and to determine the effect of salinity on growth (treatments 0, 10, and 15 ppt salinity). Fish were divided into treatment groups. For the system experiment, treatments were a control in a recirculating system, and closed systems for a second treatment with aquarium filtration systems. For the salinity experiments, treatments were 0-15 ppt salinity. Fish length and weight were measured at beginning and end of experiments (tropical gars also measured every 15 days), and were fed *ad libitum* with trout feed (tropical gars) or commercial pellet feed (Cuban gars). In all experiments, ammonia, nitrite, nitrate, and pH were measured weekly, and temperature daily. The various salinity treatments and recirculating or filtered systems resulted in no significant differences in growth for any treatment. Water quality was generally similar among all treatments as well. Overall, this experiment indicates that tropical and Cuban gars are tolerant of a range of conditions and could be reared using a variety of systems without any loss of yield. Since the various systems have different costs of maintenance and operation, this wide-ranging tolerance of rearing conditions allows gar to be reared more efficiently in systems to suit local conditions.

INTRODUCTION

Gars are a group of ancient air-breathing fishes that make up the family Lepisosteidae. The family consists of two genera, *Atractosteus* and *Lepisosteus*, and seven extant species. The genus *Lepisosteus* consists of the longnose gar (*L. osseus*), shortnose gar (*L. platostomus*), spotted gar (*L. oculatus*), and Florida gar (*L. platyrhincus*); *Atractosteus* consists of the tropical gar (*A. tropicus*), Cuban gar (*A.*

tristoechus), and alligator gar (*A. spatula*). Although the fossil record for gars exhibits a Pangeaic distribution, extant species are relegated to North and Central America and Cuba, and range from southern Canada (longnose gar) to Costa Rica (tropical gar) (Suttkus, 1963; Wiley, 1976).

Gars are top-level predators in their native ecosystems and are characterized by their elongate jaws, cylindrical bodies, and diamond-shaped ganoid scales. Their maximum size and age varies with species, from approximately 80 cm and 10 years (shortnose gar) to 300 cm and over 70 years (alligator gar). Gars are generally polyandrous in reproductive strategy, with multiple male individuals spawning with 1-2 females. Gars spawn during late spring and early summer in temperate regions and during the rainy season in tropical regions. Growth is extremely rapid, with all species capable of reaching 30 cm or more in their first growing season (young–of-the-year alligator gar can reach over 30 cm, 250 g in 3 months).

Gars are excellent candidates for aquaculture as they exhibit rapid growth to large sizes, are highly resistant to disease, can be maintained at high densities, readily adapt to artificial feed at early life stages, and are tolerant of low water quality conditions due to their air-breathing abilities (Alfaro et al., 2008). Their tolerance of low water quality via aerial respiration also allows for a less complicated technological system for aquaculture, as opposed to other fishes, which may require considerable aeration and water turnover. Gars are therefore well suited for culture in developing regions.

Much progress has already been made in the aquaculture of *Atractosteus* gars (tropical, Cuban, alligator), primarily in regions of Mexico, Cuba, and the southern United States. Broodstock for all three species have been established and are currently maintained in their native regions, and juveniles have been released to help restock diminishing wild populations. Further efforts are being made in the southern US to protect alligator gar populations and manage them as a viable sport fishery, as well as increase its potential as a food fish. Gars are already a popular food fish in various regions of Mexico and Cuba.

Due to their unique appearance and predatory nature, gars are becoming increasingly popular in the ornamental fish trade. Gars have been sought-after aquarium fish in Southeast Asia for many years and are growing in popularity in the United States and other countries. The Florida gar, native to only a small portion of the southeastern US, is the most popular aquarium species of gar in the US (usually wild-caught) and most readily available abroad. Prices in the US range from $15-40 USD for 20-35-cm individuals. Other gar species at similar sizes command a much higher price, largely due to their rarity in the aquarium trade, such as $200 USD for an individual tropical gar and over $300 USD for a Cuban gar (in the United States). Tropical and Cuban gars are also highly valued overseas; in Singapore 15-cm tropical gar average $150 USD, and Cuban gar $400 USD. Ironically, tropical and Cuban gars are among the most commonly cultured gar species. Specimens exhibiting genetic mutations in pattern or coloration (i.e., melanistic, xanthochroic, leucistic) command an even higher price, ranging from $1000 to over $5000 USD. Hybrid gars, although rare in the trade, are also much sought after.

Because gars are air-breathers, they should perform well in completely closed recirculating systems, potentially using less water for culture. Gars may also be cultured in systems with reduced or no additional aeration, further reducing energy consumption. Our experiments on recirculating and filtered systems will begin to address the potential of reducing water and energy use in the culture of gars. Several gar species have been shown to have moderate-to-high salinity tolerances (compared to other teleost and non-teleost freshwater fishes) and, in some cases, showed improved growth under saline conditions (Suchy, 2009). Furthermore, gar from different latitudes may exhibit different growth rates (latitudinal variation); therefore, specific populations may be better candidates for culture than others. By comparing our growth models with those from other regions (specifically with the wide-ranging tropical gar), we may determine the populations with the highest capacity for growth and therefore production in culture. This could be incorporated into existing operations to potentially increase efficiency, sustainability, and production, as well as making the technology for gar culture more accessible to developing regions.

OBJECTIVES

1. Determine success of closed and recirculating filtration systems on water quality and growth of gars (closed versus recirculating systems).

2. Determine the effect of salinity on growth of gars (treatments salinity 0 ppt, 5, and 10 ppt and 0, 10, and 15 ppt).

3. Evaluate the growth of gars using feed with lower fishmeal content.

METHODS AND MATERIALS

Experiment 1a. Differential growth of tropical gar in closed and recirculating filtration systems, and variation in water quality – tropical gars were divided into four treatment groups: one (control) in a recirculating system, and three in closed systems with aquarium filtration. Fish were placed in 12 plastic tanks of 170 L (triplicated). Treatments were set as follows: a) control group, 7 fish/tank in a recirculating system; b) 3 fish/tank (treatment 2); c) 5 fish/tank (treatment 3); and d) 7 fish/tank (treatment 4). The last three treatments were in closed systems. Tanks in closed system treatments used a small sponge filter to maintain water quality. Recirculating system treatment used a large central biofilter and reservoir to maintain water quality.

Experiment 1b. Differential growth of Cuban gar in closed and recirculating filtration systems, and variation in water quality – Cuban gars were randomly divided into 2 treatment groups: recirculating filtration and non-recirculating filtration. Each treatment consisted of 3 replicates (6 fish/replicate). Individuals were maintained in 170 L fiberglass tanks (1 replicate group per tank); the recirculating filtration treatment tanks were connected via stand pipe to a large recirculating system with a central biofilter (1,000 gallons) and the non-recirculating filtration treatment tanks utilized a small air-driven sponge filter. All replicates were fed commercial floating pellet feed (New Life Spectrum pellet) every other day at approximately 5-10% mean body weight of all 6 fish comprising the replicate. At the end of each week, water quality was measured (pH, NH_4, NO_2, NO_3) for each replicate, and non-recirculating tanks were backwashed for 10 minutes to help prevent excessive deterioration of water quality. Water temperature was maintained at approximately 27°C using heaters in each tank for the duration of the experiment. Experimental duration was 30 days; fish length and weight were measured at the beginning and end of the experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data (JMP/SAS Software).

Experiment 2a. Effects of salinity on growth of tropical gar – A random complete design was used with three salinity treatments: 0 (freshwater), 5, and 10 ppt. Each treatment was performed in triplicate. Fish were maintained in 1-m^3 tanks at a density of 25 fish per tank. Fish length and weight were measured every 15 days to determine growth over the course of the experiments. Additionally, we performed another trial using 0, 10, and 15 ppt of salinity (treatment 1, 2, and 3, respectively) with the same conditions.

Experiment 2b. Effects of salinity on growth of Cuban gar – Cuban gars were randomly divided into 2 salinity treatments: 0 ppt (freshwater) and 10 ppt. Each treatment consisted of 2 replicates (9 fish/replicate). Individuals were maintained in 132 L plastic injection-molded tanks (1 replicate group per tank). Each tank contained an internal underwater filter to maintain water quality. Salinity was attained using Instant Ocean commercial sea salt mix and measured weekly using a hydrometer. All replicates were fed commercial floating pellet feed (New Life Spectrum pellet) every other day at approximately 5-10% mean body weight of all 9 fish comprising the replicate. At the end of each week, water quality was measured (pH, NH_4, NO_2, NO_3) for each replicate. Water temperature was maintained at approximately

27°C using heaters in each tank for the duration of the experiment. Experimental duration was 30 days; fish length and weight were measured at the beginning and end of the experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data (JMP/SAS Software).

Experiment 3a. Fishmeal replacement in tropical gar feeds – A complete randomized design was used with five treatments in which fishmeal was substituted at different rates (0, 25, 50, 75 and 100% substitution). The experiment was started using fish that averaged 14.4 g in weight and 15.8 cm in length. Every treatment had three replicates. The gar were placed in a recirculation system (every tank stocked with 10 fish). Fish length and weight was measured every 15 days to determine growth over the course of the experiment. Every diet had a final content of 40% animal protein and 7% fat. The software Nutrition 5.0™ was used to estimate the ingredients needed to accomplish the target composition. Diets were made according to Álvarez et al. (2001).

Experiment 3b. Fishmeal replacement in Cuban gar feeds – Cuban gars were randomly sorted into 3 treatment groups with 2 replicates per group (6 fish per replicate). Individuals were maintained in 170 L fiberglass tanks (1 replicate group per tank) which were connected to a closed recirculating filtration system with a central biofilter. Each treatment group was given a different fishmeal substitution diet (0, 50, and 100% substitution) manufactured by colleagues at UJAT. Cuban gars were trained onto a commercial pelletized feed (New Life Spectrum pellets) for 2 months preceding experiment 3b in order to encourage consumption of experimental feed. Each replicate was fed once daily at approximately 5-10% mean body weight of all 6 fish comprising the replicate. Excess feed was removed after 30 minutes. Water temperature was maintained at approximately 27 °C using heaters in each tank for the duration of the experiment (30 days). Length and weight were measured at beginning and end of experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data.

Feeding – Fish for experiments 1 and 2 were fed *ad libitum* with trout feed (Pedregal®). This diet has 45% protein and 32% fat. Fish were fed 2 times a day (9:00 and 15:00 hours). For experiment 3a, fish were fed 3 times a day (9:00, 12:00, and 15:00 hours) with the targeted diet. Excess feed was removed after 30 minutes of feeding, the systems were cleaned by siphoning daily, and all filters were washed using tap water.

Water Quality – In all experiments, water quality measurements (ammonia, nitrite, and nitrate) were taken weekly, and pH and temperature daily. Water temperature was not controlled in the systems, but temperatures were recorded throughout the experiment to allow for comparison of the two culture systems. Nitrite, nitrate, and ammonium were measured using a spectrophotometer (Hanna®), pH with a Hanna® pH-meter, and temperature with an electronic thermometer (YSI®).

Growth performance – Length and weight was measured on each fish during experimental days 0, 15, and 30. Survival was calculated based on number of fish obtained at the end of the experiment.

Statistical Analysis – ANOVA tests were used to determine statistically significant differences in growth indicators and water quality parameters between treatments. The statistical analysis was performed using the STATGRAPHICS® Centurión package, and graphs were made using Sigma Plot®.

RESULTS

Experiment 1a – Differential growth of tropical gars in closed versus recirculating filtration systems. This experiment was conducted using tropical gar with an average weight and length 88.7-99.2 g and 26.5-27.5 cm. After 30 days, no significant differences were observed between treatments for mean weight or length (ANOVA; $P>0.05$). The lowest growth was observed in treatment 4, with 83.1 ± 26.4 g and 27.2 ± 2.4 cm, and the highest growth in treatment 1 (control) with 104.0 ± 8.3 g in weight and 28.7 ± 0.5 cm in length (Figure 1). Temperature ranged between 26.1 and 28.0 °C; pH between 8.2 and 8.8 IU; ammonia between 0.1 and 0.9 mg/L; nitrate between 9.7 and 86.6 mg/L; and nitrite between 0.1 and 1.4 mg/L (Table 1). Survival was 100% for treatments 1 and 2; 66% for treatment 3, and 52% for treatment 4.

Table 1. *Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.97 (± 0.65)	8.79 (± 4.27)	0.26 (±0.21)	12.82 (± 5.71)	0.57 (± 0.62)
2	26.18 (± 0.99)	8.21 (± 0.30)	0.43 (± 0.66)	66.01 (± 59.18)	0.80 (± 0.59)
3	26.16 (±1.01)	8.26 (±0.32)	0.85 (± 1.54)	86.61 (± 68.16)	1.37 (± 1.79)
4	26.13 (± 1.00)	8.20 (± 0.30)	0.87 (± 1.44)	84.75 (± 67.02)	0.85 (± 0.54)

Experiment 1b – Differential growth of Cuban gars in closed versus recirculating filtration systems. This experiment was conducted using Cuban gars with an initial average weight and length of 73.9 g and 26.4 cm, and ending with a final mean weight and length of 84.3 g and 26.8 cm, respectively. After 30 days, no significant differences were observed between treatments for mean weight or length (ANOVA, $P>0.05$; Figure 5). Water chemistry parameters did not vary significantly for the duration of the experiment in either treatment. Survival was 100% for all treatments.

Experiment 2a – Effects of salinity on growth of tropical gar. Fish used in this experiment had an initial weight of 142.6 g (±1.7), 135.8 g (±4.3) and 138.2 g (±1.6) for 0, 5, and 10 ppt, respectively; and 30.6 cm (±0.1), 30.17 cm (± 0.2) and 30.1 (±0.1) cm for initial length. After 30 days, ANOVA indicated no statistically significant differences in weight or length among treatments ($P>0.05$). Fish achieved average weight of 165.0 g (±9.5) for 0 ppt, 150.1 g (±8.4) for 5 ppt, and 145.0 g (±16.3) for 10 ppt of salinity (Figure 2). The results in length were 32.1 cm (±0.3), 31.3 cm (±0.5), and 31.3 cm (±0.9) for 0, 5, and 10 ppt, respectively.

Water quality parameters remained relatively stable (Table 2); but a significant rise in ammonia, nitrate, and nitrite was observed for treatment 3 (10 ppt). Survival for this experiment was 100% for treatment 3, 98.7% for treatment 2, and 93.3% for treatment 1.

Table 2. *Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.59 (±0.75)	7.83 (±0.55)	2.06 (±1.56)	10.30 (±15.41)	0.63 (±0.72)
2	27.65 (±0.61)	7.70 (±0.29)	1.53 (±1.85)	16.50 (±17.63)	1.06 (±1.37)
3	27.56 (±0.63)	7.46 (±0.34)	2.59 (±2.18)	35.02 (±51.19)	1.70 (±0.62)

For the second trial, there were also no statistically significant differences among treatments for length or weight gain. Fish reached an average of 189. g (±18.7) in 0 ppt, 166.0 g (±20.5) in 10 ppt, and 159. g (±9.) in 15 ppt of salinity. The average final length results were 33.1 cm (±0.7), 31.9 cm (±0.7), and 31.7 cm (±0.3) for 0, 10, and 15 ppt, respectively (Figure 3).

Water quality parameters again remained relatively stable in this trial (Table 3); but a significant rise in ammonia, nitrate, and nitrite was observed for treatment 3 (15 ppt). Survival for this experiment was 100% for treatments 2 and 3, and 97.3% for treatment 1.

Table 3. *Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.63 (±0.57)	8.30 (±0.20)	2.58 (±0.72)	0.81 (±1.34)	0.53 (±0.59)
2	27.81 (±0.60)	7.55 (±0.34)	1.12 (±0.38)	0.50 (±1.86)	0.14 (±0.65)
3	27.73 (±0.62)	7.33 (±0.47)	5.08 (±5.67)	9.15 (±10.99)	0.73 (±0.62)

<u>Experiment 2b – Effects of salinity on growth of Cuban gar.</u> Fish used in this experiment had an initial mean weight of 84.6 g and 27.4 cm for initial mean length. Final mean weight and length was 91.9 g and 27.8 cm, respectively. After 30 days, ANOVA indicated no statistically significant differences in weight or length among treatments (P>0.05; Figure 6). Water quality parameters did not vary significantly among replicates or treatments for the duration of the experiment, and survival was 100% overall.

<u>Experiment 3a. – Fishmeal replacement in tropical gar feeds.</u> After 105 days, no significant differences were found for weight or length among gar grown under each experimental diet (ANOVA P>0.05; Figure 4). Growth indicators are shown in Table 4. A significant increase in weight (262.2-323.9% gain) and length (45.8-54.16% gain) was obtained in this experiment. Daily growth varied between 0.40 and 0.48 g. Food Conversion Rate (FCR) was very similar in all treatments ranging from 1.18 to 1.30. The highest FCR was observed for the fish fed with no fishmeal substitution and the lowest for the fish with 50% substitution. Table 5 shows growth indicators, FCRs, and final biomass obtained.

Survival was very high in all treatments. No significant differences were found between treatments (Chi square, P > 0.05). In diets with 25 and 75% substitution, we obtained 100% survival; 97% for diets with 50 and 100% substitution, and 90% for the control diet. Water quality was good along the experiment. Water temperature averaged 28.4°C. Dissolved oxygen remained relatively high (6.1±0.1 mg/l) and pH was slightly basic (7.6).

Table 4. *Average Weight and length (±SD) and growth indicators after 105 days of experimentation.*

Variable	Treatment				
	Control (0% substitution)	***Diet 1 (25% substitution)***	***Diet 2 (50% substitution)***	***Diet 3 (75% substitution)***	***Diet 4 (100% substitution)***
Initial Length (cm)	15.8±7.4	15.9±7.3	15.7±7.6	15.9±7.7	15.7±7.1
Final Length (cm)	23.5±20.2	23.2±17.0	24.1±17.4	24.0±18.4	24.1±16.1
Initial Weight (g)	14.4±1.83	14.5±2.0	14.2±2.1	14.1±2.4	14.0±2.8
Final Weight (g)	56.1±13.5	52.4±12.1	58.9±13.0	56.3±14.5	59.3±13.5
AG (cm)	7.75±0.49	7.28±0.22	8.52±0.21	8.17±0.65	8.41±0.41
AGR (cm/d^{-1})	0.08±0.01	0.08±0.00	0.09±0.00	0.09±0.01	0.09±0.00
AG (g)	41.68±3.09	37.9±1.81	44.78±1.31	42.21±3.41	45.31±3.42
AGR (g/d^{-1})	0.44±0.03	0.40±0.02	0.47±0.01	0.44±0.04	0.48±0.04
RG Length (%)	49.15±2.89	45.80±2.32	54.16±1.48	51.49±4.61	53.53±2.8
RGR Length ($\%/d^{-1}$)	0.52±0.03	0.48±0.02	0.57±0.02	0.54±0.05	0.56±0.03
RG Weigh (%)	288.86±17.32	262.23±21.48	315.61±15.71	300.26±23.52	323.95±23.23
RGR Weight ($\%/d^{-1}$)	3.04±0.18	3.76±0.23	3.32±0.17	3.16±0.25	3.41±0.24

AG: Absolute Growth; AGR: Absolute Growth Rate; RG Relative Growth; RGR Relative Growth Rate.

Table 5. *Average values (±SD) of growth indicators, FCR and Biomass.*

Variable	Treatment				
	Control (0% substitution)	***Diet 1 (25% substitution)***	***Diet 2 (50% substitution)***	***Diet 3 (75% substitution)***	***Diet 4 (100% substitution)***
SGR ($\%/d^{-1}$)	1.43±0.0	1.35±0.1	1.50±0.0	1.46±0.1	1.52±0.1
FCR	1.30±0.1	1.30±0.1	1.18±0.1	1.21±0.1	1.27±0.1
CF	0.43±0.0	0.42±0.0	0.41±0.0	0.40±0.0	0.42±0.0
FB (g)	1,082±27.5	1,137±18.1	1,283±22.2	1,266±34.1	1,299±48.8

SGR: Specific Growth Rate; FCR: Food Conversion Rate; CF: Condition Factor; FB: Final Biomass.

Experiment 3b. – Fishmeal replacement in Cuban gar feeds. After 30 days, significant increase in weight occurred over all treatments, however, no significant differences were found for weight or length among Cuban gars grown under each experimental diet (ANOVA, P>0.05; Figure 7). Initial mean weight was 61.9 g and length 25.5 cm, with final mean weight 73.9 g and length 26.5 cm. Survival was 100% for the duration of the experiment, and water quality parameters did not vary significantly among treatments.

DISCUSSION

In this study, closed or recirculating filtration systems or different salinity conditions did not affect growth indicators and survival for tropical and Cuban gars. In the recirculating system growth was slightly better for tropical gars. This could be due to better water quality conditions, since ammonia, nitrate, and nitrite were lower than in the tanks with aquarium filters. Another factor that differed in experiment 1a was the temperature (by 1.5 degrees), which could have enhanced growth. This was reflected in food intake since fish had better appetites in the recirculating system and showed more swimming activity. Survival was better in the recirculating system and tanks with the lowest density (3 gar/tank); but this difference was small. Since water quality conditions deteriorated as the trial advanced, it is possible that mortality in higher densities and aquarium filtration would be worse after a longer period of time. Gar can tolerate high levels of nitrogen in the water, but at a certain point, nitrogen levels could damage gills and kidneys (Boudreaux et al., 2007). Several authors have demonstrated that fish have better health and growth indicators under recirculating conditions; the freshwater eel is an example of having survival rates up to 91% (Suzukia et al., 2003). In another experiment, De la Mora et al. (2003) obtained 99% survival for tilapia (*Oreochromis niloticus)* and rainbow trout (*Oncorhynchus mykiss)* in recirculating systems with different biomass (13 and 98 kg/tank). In these experiments, the fish were kept in systems for 120 days, water quality was always optimal, and growth estimates were acceptable. Jiménez-Martínez et al. (2009) evaluated different densities of *Petenia splendida* and *Cichlasoma urophthalmus* larvae in recirculating systems for 45 days. The lowest densities (0.5 and 1 larvae/L) presented the highest growth for both species. The disadvantage of lower densities was that a lower amount of fish was obtained per tank.

The confinement of fish under brackish water conditions (5-15 ppt) did not affect weight, length, or survival of the tropical or Cuban gar juveniles; but in experiment 2a, the fish kept under freshwater conditions showed a slight increase in weight. This was valid for both trials performed on tropical gars and the highest salinities evaluated (10 and 15 ppt). Despite the short experimental period, tropical gars in freshwater grew 15-22 g more than the other fish. This is the first time in which tropical and Cuban gars have been evaluated under brackish water conditions. While anecdotal information from anglers indicates that tropical gars do not venture into brackish water, they have been seen in coastal lagoons with these conditions. A possible explanation for this is that gars are frequently parasitized by freshwater sea lice (*Argulus spp.*) and may enter brackish water to eliminate them from the skin. In several freshwater species, confinement in brackish water does not affect growth. Tilapia is a good example of this, since they maintain growth even at sea water conditions (Mena-Herrera et al., 2002). In some cases, salinity acting together with temperature may cause lesions to the fish; this has been reported in tilapia juveniles (Linkongwe et al., 1996). We did not observe lesions in the body or gills of the gar in our study, but a prolonged confinement may cause such problems. We have used salt in the water as prophylactic treatments to eliminate sea lice in gars; the results obtained in our experiments indicate that even long treatments can be used for this species causing no harm to the fish.

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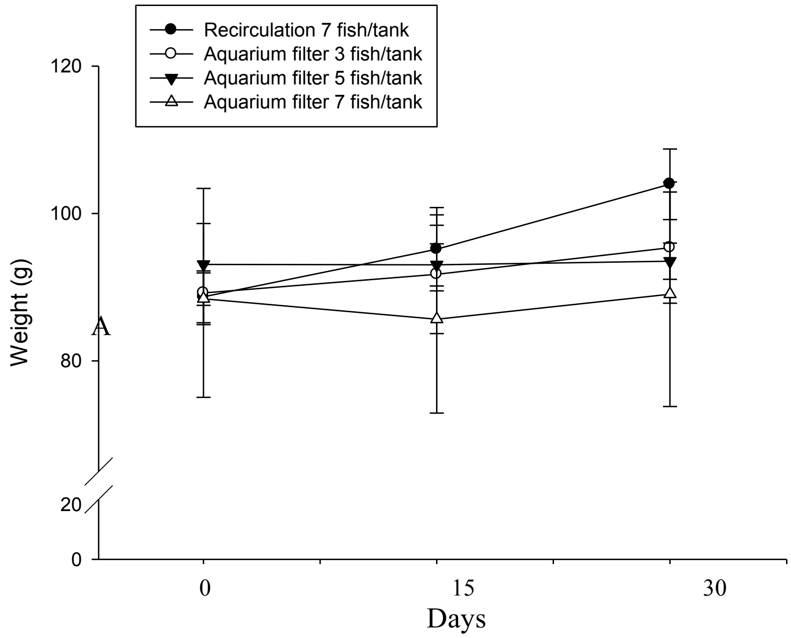


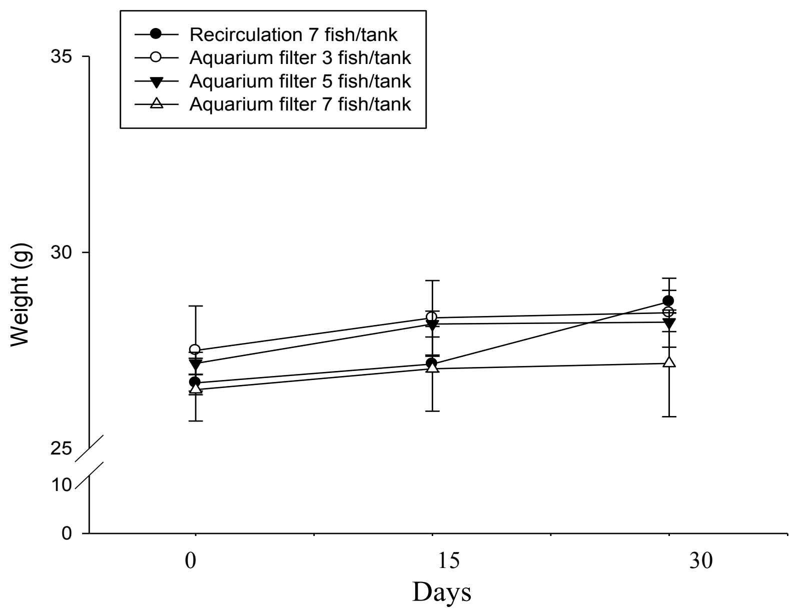
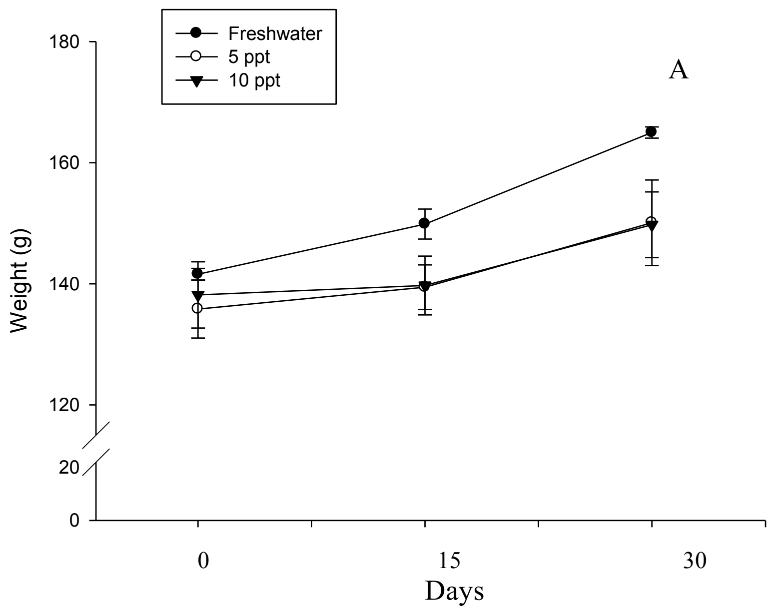


Figure 1. *Average weight (a) and total length of tropical gar juveniles confined in closed and recirculating systems (experiment 1).*



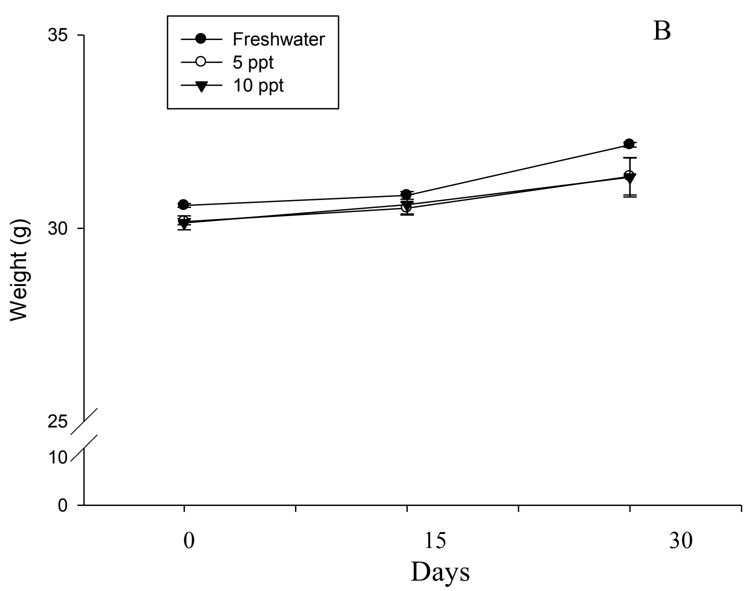


Figure 2. *Average weight (a) and total length of tropical gar juveniles kept under different salinity conditions (experiment 2; trial 1).*

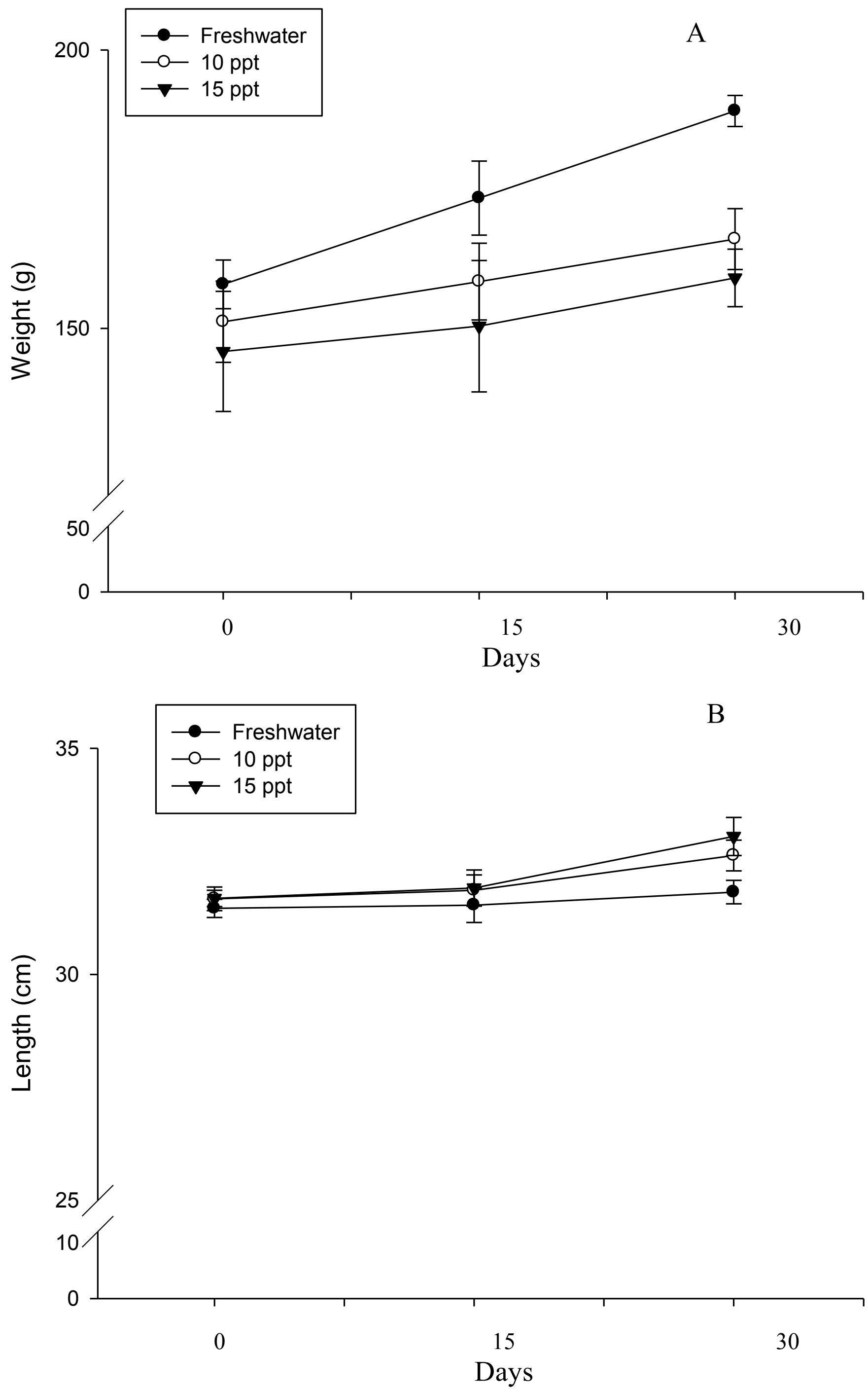


Figure 3. *Average weight (a) and total length of tropical gar juveniles kept under different salinity conditions (experiment 2; trial 2).*

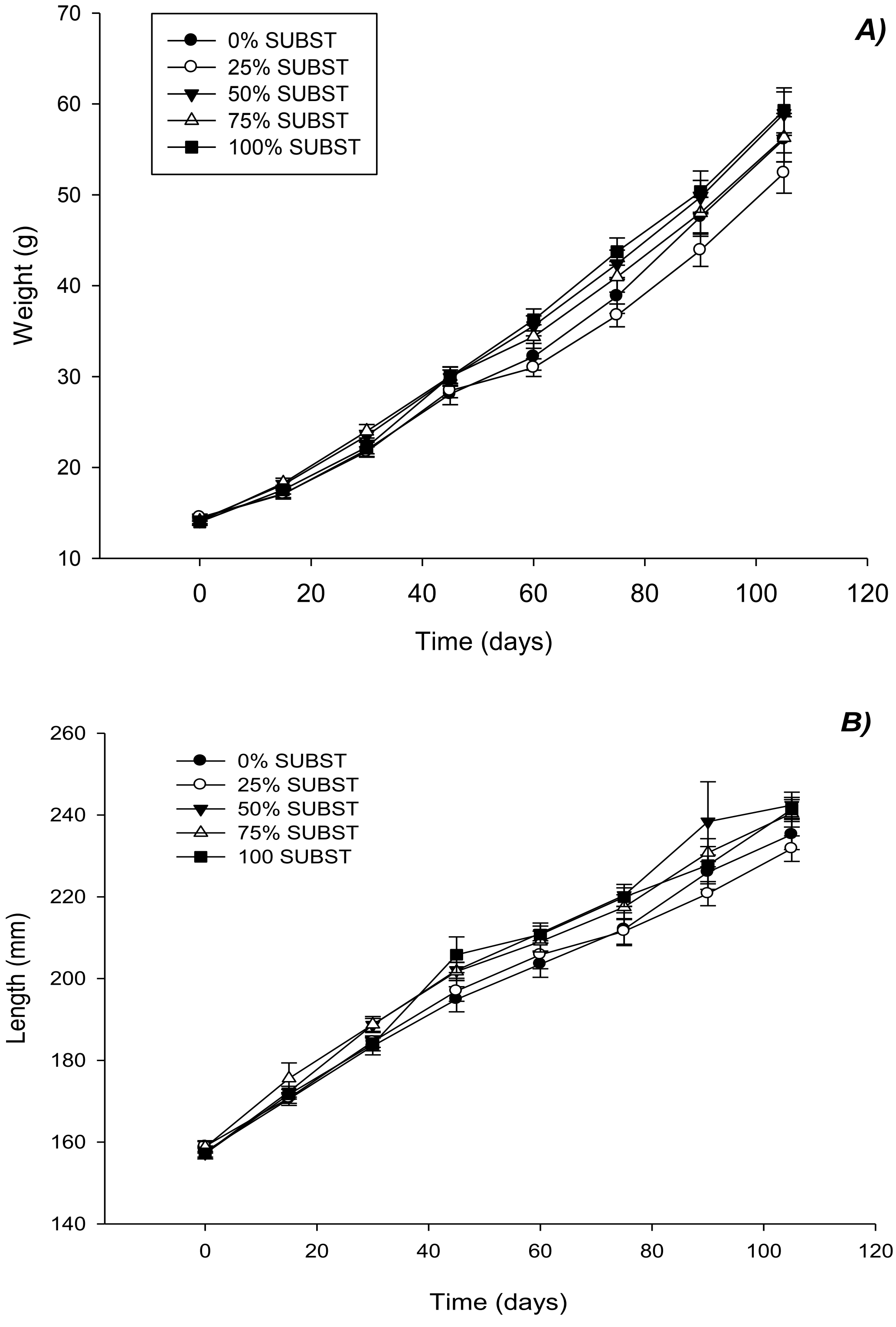


Figure 4. *Average values for (±SD) weight (A) and length (B) in tropical gar juveniles fed with different rates of fish meal substitution (0, 25, 50, 75 and 100%) with meat meal.*

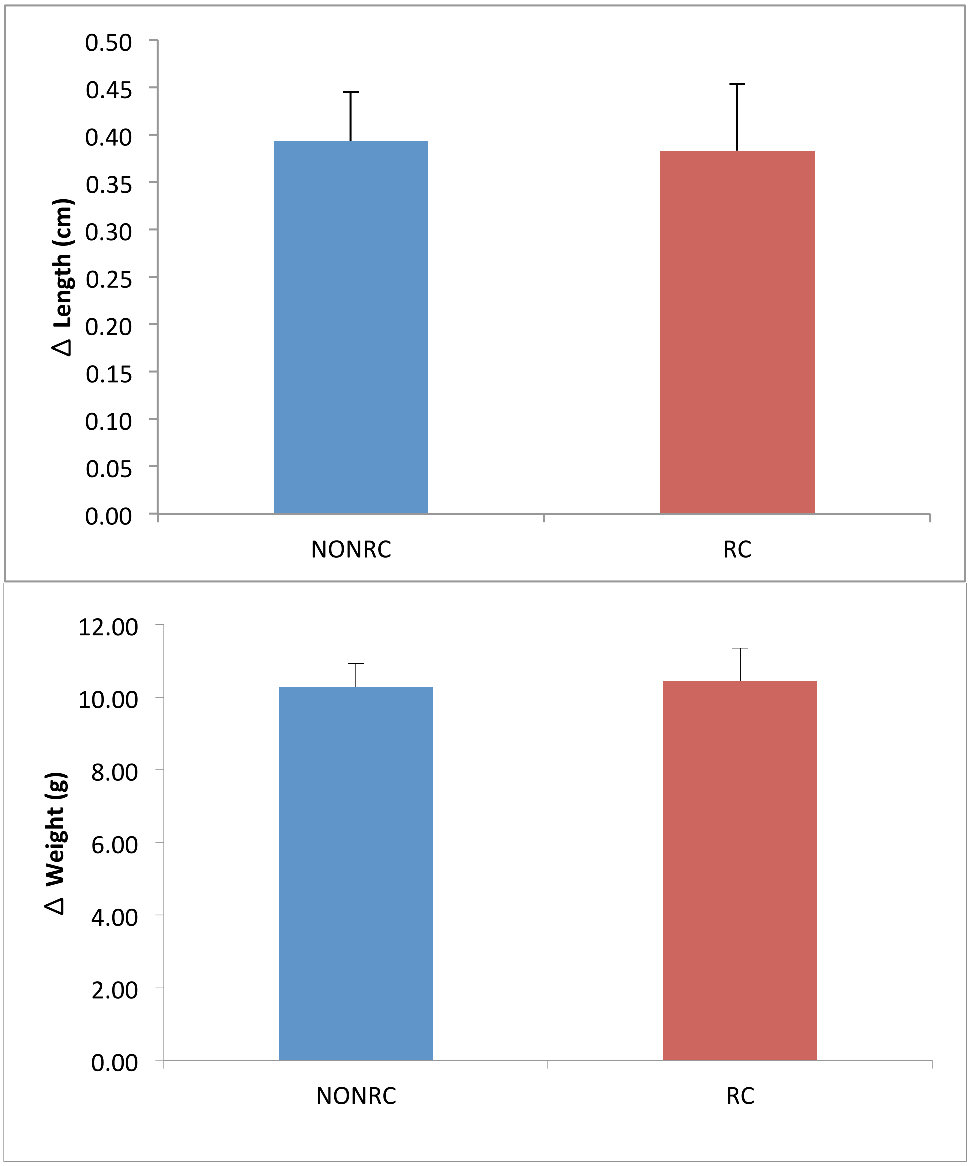


Figure 5. *Increase in length and weight of Cuban gars in experiment 1b. NONRC = Non-recirculating filtration, RC = recirculating filtration. ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*

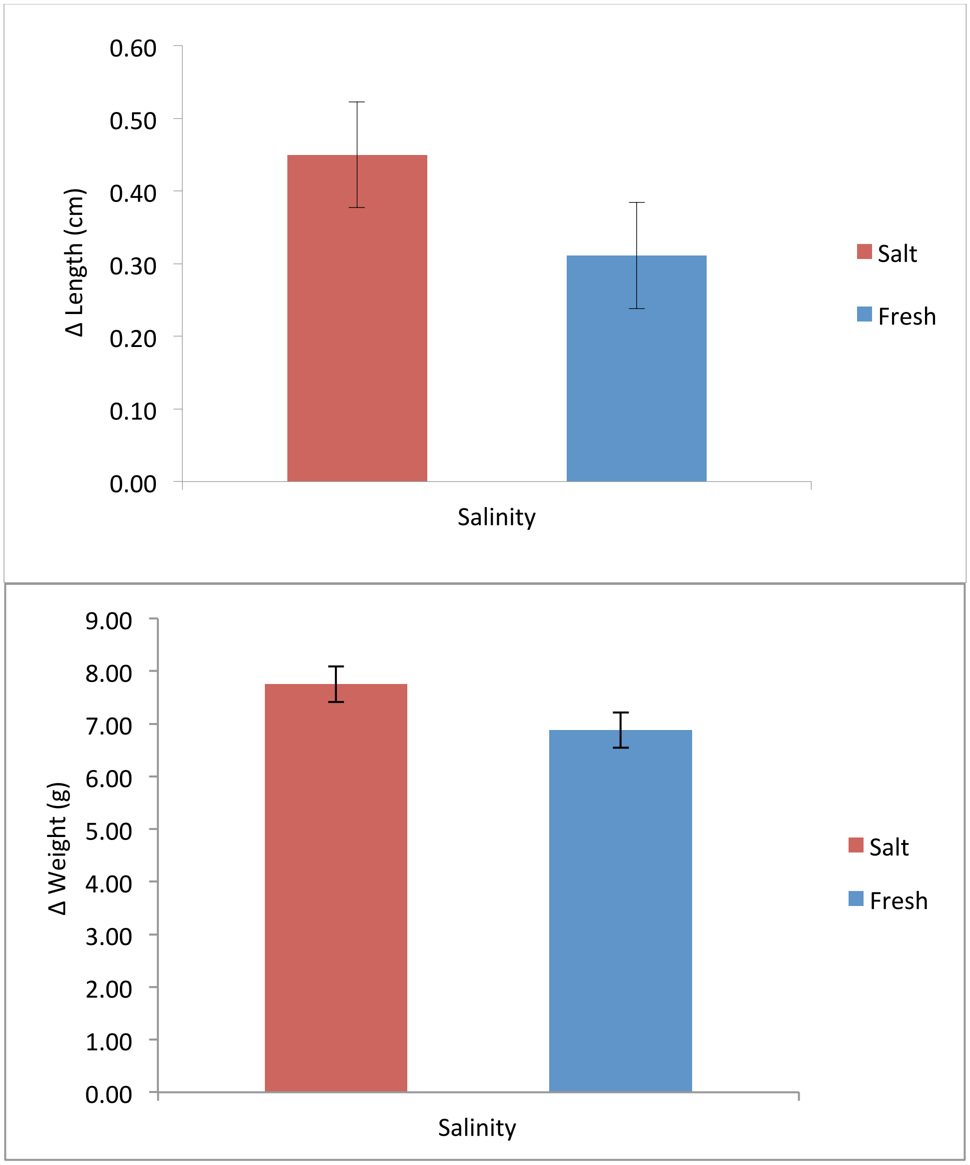


Figure 6. *Increase in length and weight of Cuban gars in experiment 1b. Salt = 10 ppt, Fresh = 0 ppt (freshwater). ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*

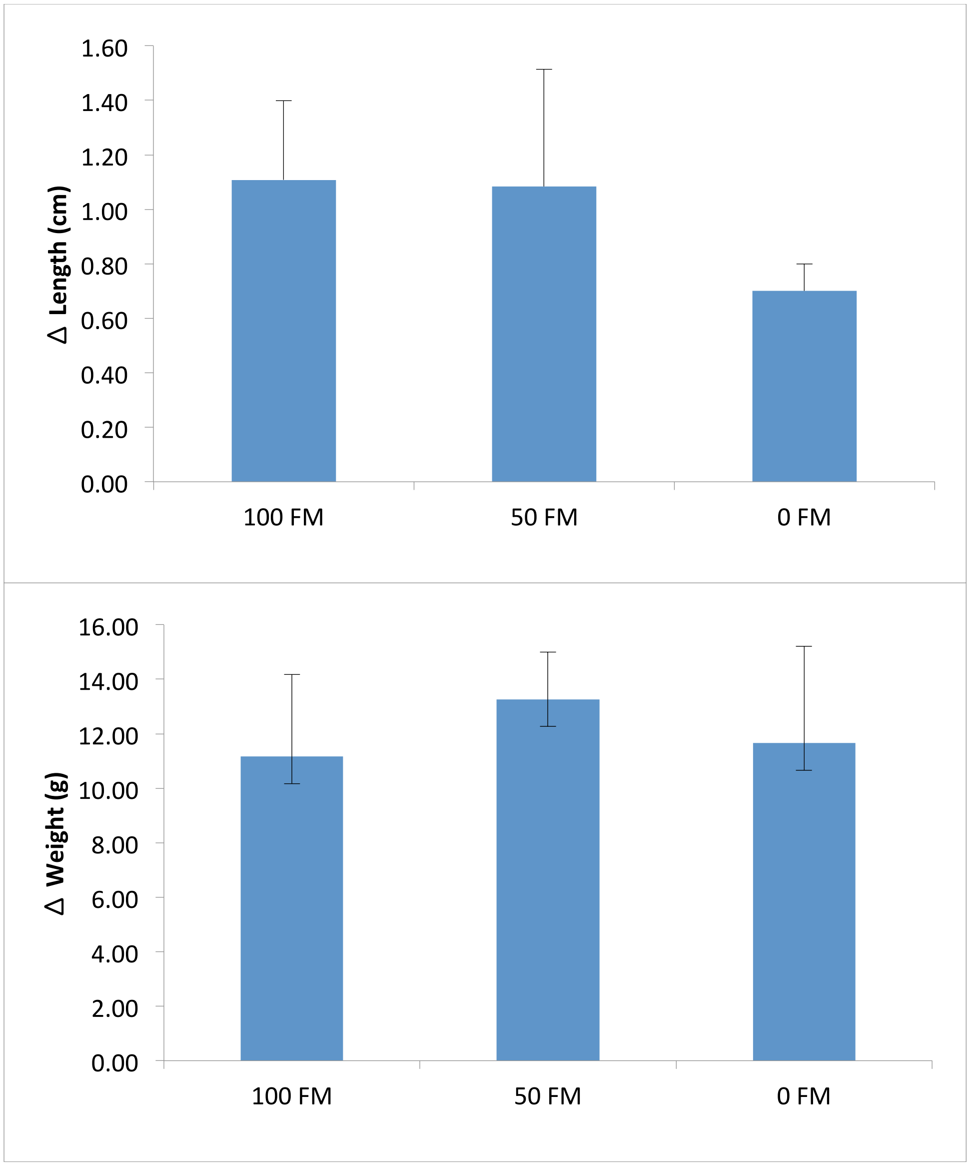


Figure 7. *Increase in length and weight of Cuban gars in experiment 3b. 100 FM = 100% fishmeal, 50 FM = 50% fishmeal, 50% beef by-products, 0 FM = 0% fishmeal, 100% beef by-products. ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*

TOPIC AREA:
VALUE CHAIN ANALYSIS

❖

VALUE CHAIN ANALYSIS OF SEAWEED IN ACEH, INDONESIA

Marketing, Economic Risk Assessment & Trade/Activity/09MER06NC

FINAL INVESTIGATION REPORT

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ABSTRACT

This study analyzed the value chain of seaweeds (particularly *Gracilaria*) for Banda Aceh, Indonesia, including the roles of key players, logistical issues, external influences, and transaction flows among market levels. The study identified areas for improvement and provided recommendations for the Indonesian seaweed industry, in general, and the Banda Aceh seaweed farmers, in particular.

Key players of the seaweeds industry are the seaweed farmers, collectors (or assemblers), interregional shippers/traders, and provincial/regional processors and exporters. Jakarta, Sulawesi, and Surabaya are the major transshipment points of tradable seaweed products either in dried or derivative forms. Dried seaweeds (about 80%) are exported for further processing into agar and carrageenan and imported back to meet its domestic demand for food, pharmaceutical, industrial, and energy sectors. Domestic demand for seaweed derivatives is fast growing in many seaweed raw material sources such as Indonesia, the

Philippines, and other Southeast Asian countries, thus, putting downward pressure on the availability of raw material supply in the global markets.

The technological advances of the seaweed derivatives market (downstream subsector) had clearly outpaced those in the upstream subsector including the reliability and quality of planting materials, and cultural and post-production practices of dried seaweeds, among others. Hence, the mismatch of information on grades and standards is one of the major reasons for disparities of growth among the key players in the seaweed industry.

Because of the geographic locations and state of marketing infrastructures in rural Indonesia, the major problem of the seaweed industry is the very weak linkage of the raw material subsector to the seaweed derivatives and end-user subsectors. These problems include high logistics and transaction costs across the value chain, lack of seaweed laboratories and nurseries, lack of postharvest technologies and facilities at the farm level, irregular supply of desired quality, and volume of dried seaweed.

The levels of public and private investment in research and extension coupled by the geographic distribution of seaweed farming communities should require a shift in business and/or marketing strategies. The traditional marketing modes should now be replaced by more strategic ones, like the value (or supply) chain management schemes, joint ventures, and/or other coordinating mechanisms.

Some recommendations to address the issues and concerns are: encourage the establishment of more seaweed laboratories, nurseries or multiplier farms; establish more cluster-based post-harvest facilities; institutionalize an accreditation program for seaweed derivatives processors and manufacturers of end-products, etc.; and provide capital windows to improve facilities and enhance the entire management of value chains of the seaweed industry.

INTRODUCTION

Seaweed is one of the most dynamic fishery products in Indonesia. It continually provides livelihood and employment activities to small fishing folks in coastal areas. It attracts new investors while some established ones improve their products and processes to meet increasing demand of global markets. Likewise, it is a stable source of export earnings of the country. Finally, it opens up new niches in the food, pharmaceutical, industrial and energy markets.

Seaweeds (or sea plants) are salt-water algae that grow in shallow coastal areas and ponds near waterways. They are classified as Green, Brown or Red and each classification has a number of Genera and Species. Red seaweeds (e.g. *Gracilaria*) are the major varieties farmed in Indonesia and Southeast Asian countries, hence the interest of the study.

Seaweeds are the major sources of agar and carrageenan. Both are large, highly flexible molecules with curl forming helical structures, thus, enabling them to form a variety of different gels at room temperature. Carrageenan and agar are widely used in food and other industries as thickening, stabilizing and/or emulsifying agents for making primary products such as chocolate milk drinks, ice cream, dessert gels and flans; sauces and dressings; beef patty, luncheon meat, poultry and ham; beer, wine and vinegar; toothpaste, shampoo and cosmetic creams; pharmaceuticals, shoe polish, pulp and paper, ceramic coatings, carpet printing, and other products.

The demand for agar and carrageenan is derived from the demand for the above-cited primary products. However, the sluggish performance in the value-adding subsector of the Indonesian seaweeds industry and the relative inefficiencies in the marketing system remain vital challenges of the industry, by and large. To be a strong contender in the global market of seaweeds given its geographic features and comparative advantages, Indonesia should capitalize more in the value-adding aspect of the industry and translate the gains to the smallholder farming communities, thus alleviating poverty in the process through a more responsive value (or supply) chain.

OBJECTIVE

The goal of the study is to foster the successful participation of small-scale Aceh seaweed polyculture producers in the Indonesian seaweed production/marketing system. The objectives are as follows:

1. Describe and evaluate the existing value chain of seaweed production in Aceh Indonesia.
2. Develop recommendations to improve local system efficiency and participation of small-scale seaweed polyculture producers in Aceh Indonesia.

METHODS

Seaweed value chain maps were traced for each market level, e.g., producer, assembler/collector, transporter, wholesaler and exporter, to identify specific activities and services, key players, logistical issues, external influences, and flow of product, information and payment. Seaweed value chain performance in Indonesia will be evaluated for efficiency, flexibility, and overall responsiveness. This method is guided by the framework of McHugh (2003), Tveras and Kvaloy (2004), and Neish (2008).

Study Areas and Coverage

In-country data collection was accomplished and interviews conducted from May to August 2012, by Jamandre with the assistance of Hasanuddin and Kokarkin. The focus of this in-country effort was Ujung Batee Aquaculture Center (UBAC) in Banda Aceh, Samalanga demonstration site in Bireun District, Lancang in Pidie District, Trengadring Multi Species Hatchery in Pidie Jaya District, Bayu in Aceh Utara District, Banda Aceh local markets, and Tangerang, East Jakarta, Cikarang, Medan and Jakarta regional markets.

Data Collection and Requirements

Primary data were obtained through survey, key informant interviews and focus group discussions (FGD). FGDs were also conducted to validate secondary information and to answer more specific questions related to value chain mapping.

The following primary data were collected: the key players and their respective roles, activities and services provided at each step in the value chain; product requirements (especially quality standards); information and money flow; critical logistics issues (including problems in production and marketing); and extension services and external influences.

Secondary data series on seaweed statistics were obtained from various Indonesian agencies, especially Ministry of Marine Affairs and Fisheries. Previous studies on the production and marketing of seaweed served as sources of secondary information. Likewise, UBAC and in-country collaborators served as sources of secondary information. Officers and staff of appropriate government agencies and other industry personalities were additional sources of information.

Data Processing and Analysis

The method of analysis of data and information for each objective is listed in Table 1.

Table 1. *Objectives and methods of analysis*

Objectives	Method of Analysis
• Develop the value chain maps • Identify improvement areas	• Flowchart analysis • Gross margin analysis

RESULTS AND DISCUSSION

<u>Overview of the Indonesian Seaweed Industry</u>

Production of Seaweeds

The major producing provinces of seaweeds in Indonesia are shown in Table 2 where South Sulawesi, Central Sulawesi and East Nusa Tenggara dominated the top three spots for the years 2007-09. During the same periods, the average annual growth rate of seaweed production rose to 32.46% across all provinces in Indonesia, with Gorontalo and Central Sulawesi as leaders with their respective growth rates.

Smallholder farmers or fisher folks undertake *Gracilaria* and *Cottonii* seaweed production, but the farming systems are distinct for the two crops. *Gracilaria* cultivation is in ponds while *Cottonii* culture is undertaken in shallow ocean water along the shoreline.

Cultivation of *Gracilaria* takes place in ponds that are located close to waterways that can be supplied with seawater. It is grown as a monoculture or in polyculture with milkfish and prawns. Most ponds are located relatively near to the coastline for both access to seawater and transportation. Production cycles are around 45 days or about 7 cycles/year. But because of water shortages during July to November in some locations, 4 cycles/year are more common.

Seaweeds Harvesting and Handling Operations

Gracilaria are grown to about 1 kg or more before they are harvested. Farmers harvest their crop by uprooting the full-grown seaweeds and taking the harvests out in pond paddies using small rafts. Seaweeds are sometimes packed in nylon sacks and transported to a farmer's shed or working area for subsequent operations.

With good and stable sunlight, seaweeds could be thoroughly dried down to about 30-35% moisture content (MC) in three to four days. This is the ideal MC for packing seaweeds. Indicators for well-dried seaweeds with about 30-35% MC include seaweeds covered with salt crystals with rubber-like texture and have no dripping water when squeezed. About 7kg to 10 kg of fresh seaweeds yield 1 kg of dry seaweeds.

Production of Agar

About 25% of the weight of dried seaweed is agar. Agar is a marine colloid extracted from certain algae of the class Rhodophyceae. It is insoluble in cold water but soluble in boiling water to make a liquid which, when cooled, forms a firm, clear, resilient gel possessing suspending, stabilizing and thickening properties. Agar can be extracted through an industrial process (Figure 1).

The processing of agar involves washing the seaweed, heating it in water and treating it with alkali (to increase the gel strength). The hot liquid is then filtered and the filtrate is cooled to form a gel. The water is then removed from the gel by squeezing and then the gel is dried. The gel is then milled to produce a fine agar powder or sometimes extruded as agar strips (see McHugh, 2003 for a detailed description). About 90% of agar is used for human consumption.

Apparently, *Gracilaria* became an important source for agar production because it is easily harvested and cultivated. Recent estimates place the annual world production of agar at about 8,000 tons. Nowadays, about 60% of agarophytes collected for agar production are attributed to *Gracilaria* spp., 35% to *Gelidium* sp. and 3% to others.

Some countries have abundant agarophyte resources, such as Chile, the Philippines, Brazil, Portugal, and Indonesia, and they export agarophytes to other regions. Japan imports a large amount of *Gracilaria* every year from these regions. Table 3 indicates the quantity of agarophytes imported by Japan.

Various studies have shown that seaweed farming is a growing agribusiness sector of Indonesia with bright prospect as a major source of income of fishing communities of the country. However, in order to realize the potential of the industry, there is a need to step up the provision of support services along with polyculture research and extension to enhance the fishermen's capability to produce and handle larger volumes of high quality seaweeds (Hatch, 2010; Jamandre et al., 2010).

Trade Performance of Indonesian Seaweeds

Seaweeds are traded globally both in raw and processed derivatives in the form of agar and carrageenan. The continued growth of the global seaweed production (Table 4) is indicative of the increasing market demand for the above primary products. In terms of wet volume equivalent, the Philippines is the world's top producer, with a share of around 32%, while Indonesia is fourth with about 10% contribution. But in terms of growth rate, Indonesia ranked first with 18%, followed by China with 15%, and the Philippines with 10%. Japan and others posted negative growth rates during 1999-2003.

Indonesia had taken the lead in the production and exports of dried seaweed from the Philippines (Table 5). The exports volume of dried seaweeds of Indonesia had grown by about 19% with an average value of US$33 million during 2000-05 while the Philippines registered a decline of around 6%. However, the Philippines has gained more in the exports of agar and carrageenan, in terms of volume and value. Hence, there is about US$40 million advantage of the Philippine over Indonesia on total value of exports.

Moreover, the world's major producers of carrageenan are the Philippines, Indonesia and China, with a combined share of about 70% (Table 6). The Philippines carries a lion's share of about 40%, which is around two to threefold higher than Indonesia and China, respectively. These gains could be attributed to the improved technologies and standards adapted in the value-adding activities of the Philippines through investment in research and extension, and strong market linkages and alliances at the various levels of the industry. These efforts should be emulated by Indonesia.

The major regional destinations of Indonesian dried seaweed are China, Europe and Asia Pacific, with a combined market shares of 40% (Table 7). Although these markets produce dried seaweeds too, Indonesian supply will certainly serve as buffer to ensure sustainable operations for their domestic requirements. For instance, the domestic markets for food, pharmaceutical and industrial grades of seaweeds absorb almost 95% of their local production. Other seaweeds are thinly distributed in America, Africa and Middle East regions. However, Asia Pacific and America are buying more aggressively than China and Middle East regional markets with respective growth rates of 45% and 39% for the same periods.

For the seaweed derivative markets, the total value of agar exports from Indonesia is almost twofold higher than that for carrageenan exports from 2000 – 2005 (Table 8). This is because *Gracilaria* as a major source of agar in Indonesia is becoming more attractive and a preferred variety. Albeit the price/tonne of carraagenan is relatively higher than agar, this may not be true for some regional markets such as Asia Pacific and Europe, where agar is more expensive than carrageenan. There is no clear pattern of prices across the regional markets but in aggregate, carrageenan remained more expensive than agar.

Recently, the Indonesian export earnings from dried seaweeds (88%) and gelatin/agar (12%) amounted to an annual average of around US$96M during 2007-09 (Table 9). The variance of the unit values of the two commodities may be translated as export opportunities with improved processing technology by the seaweed-producing sector.

Table 10 corroborates further the advantages of undertaking downstream processing activities. The price differential across grades of processed carrageenan and dried seaweeds indicate premium for quality standards. Since Indonesia is exporting 80% of its dried seaweeds it is clearly missing this opportunity.

The shipping cost schedules of dried and processed seaweed derivatives to domestic and foreign destinations show the presence of cost savings by complying with the product grades and packaging requirements (Table 11). The gross margin per kilogram of dried *Gracilaria* is shown in Table 12. There is a premium of improving quality even within product grades. In this case, three classes of dried *Gracilaria* are compared with assorted ones and the gross margin or profit per kilogram increases to about two to tenfold more than the assorted ones. Due to the clear economic benefits of engaging in the value adding activities, more domestic processors are expanding and/or improving their outfits to conform with the world standards (Table 13).

Value Chain of Dried Seaweeds and Derivatives

There are three major segments or subsectors of the entire value chain of the Indonesian seaweeds industry: the raw (dried) seaweed, the seaweed derivatives (agar and carrageenan), and the end-users such as the food, pharmaceutical, industrial and energy subsectors. The first subsector is the focus of this study. Generally, the chain is characterized by the interdependence of the sources of planting and other farm inputs, smallholder farm production, collection or consolidation, and transport of products to local ports for either domestic or international customers.

Key Players, Major Roles, and Activities

The major players of the Indonesian agar value chain are the *Gracilaria* farmers, producers (or processors) of dried seaweeds and seaweed derivatives, collectors, traders (or interregional shippers), and exporters. Figure 2 presents the key players together with the product flow of dried seaweeds and its derivatives.

Seaweed Farmers

Families engaged in seaweed farming consider the following factors for better yield:

Location of the farm, which has the foremost bearing on the salinity of the water. The ideal salinity is between 32 and 38 ppt. Location also influences the water temperature, which is an important factor in seaweed farming. The ideal temperature is between 27 and 30^{o}C. Location also implies that water depth should not be less than 30 cm during the low tide in order to avoid exposing the plants to direct sunlight and air. On the other hand, seaweed should be “planted” high enough to allow sunlight to penetrate the water, providing the most crucial element for photosynthesis.

Secondly, the water current should not be too rough or too gentle. The recommended water current is one that could sway the seaweeds to about 45^{o}C. This is roughly about 20-40 meters/minute. Other considerations in seaweed farming include: availability of planting materials and good marketing environment (prices and outlets).

Production Practices

Seedlings

Seaweeds are grown from seedlings that usually come from a mature harvested plant. Farmers either buy or produce their own planting materials. For those who produce their own planting materials, the shoots from the newly harvested crop are cut off to become the seedlings for the next cropping cycle. Other farmers opt to buy their planting materials from neighboring seaweed growers, especially if they want to have new stocks for better plant growth.

Planting

Seaweeds are grown and harvested in around 45 days, which typically results in 4 production cycles per year, depending on water availability. Seaweed seedlings are carefully tied to a rope using soft plastic straw before planting directly in ponds.

Postproduction Practices

Harvesting

Seaweeds are allowed to grow to 1 kg or more before they are harvested. Whole plants of *Gracilaria* are harvested or uprooted directly from ponds.

Drying

With good sunlight, seaweeds could be thoroughly dried down to about 30% moisture content in three to four days. It was cited by farmers that seven kilograms of fresh seaweed yields 1 kg of dry material. Different drying practices are enumerated, as follow:

1 Harvested seaweeds are laid and spread on finely braided nylon mesh sheets or nylon sacks sewn together, on the ground to dry under the sun.

2 Others dry their harvest on bamboo or wooden racks lined with nylon mesh or sacks as protective sheet. These bamboo or wooden slats serve as "drying pavements".

3 Seaweeds are directly spread on uncovered pavement, along pond aisles or roads and/or soil, as observed in some parts of Tangerang. This practice results in heavily soiled seaweeds.

To facilitate drying, the seaweeds are regularly turned over. However, Seaweeds that are dried under direct sunlight, without cover during drying results in very dark seaweeds.

Packing and storing

Seaweeds of about 30-35% moisture content are ready for packing. Seaweeds are tightly packed in jute or nylon sacks.

Farmers do not store their produce; instead, these are immediately collected by local collectors or village-based collectors of traders and are brought to storage or warehouses. Before packing, a certain degree of cleaning is practiced, where pebbles, stones twigs, and other foreign materials are separated from the dried seaweeds. However, fine soil materials and sand that adhere to the seaweeds are most often not removed. Contaminated seaweeds are especially observed in areas where drying is done directly on the soil surface without the use of protective sheets.

Most traders have facilities for storing their purchased seaweeds, for economies of scale and better future price consideration.

At the trader's level, properly dried seaweeds can be stored up to six months without quality deterioration; however, traders do not usually store the crop for a long period of time due to price considerations.

Marketing Practices

Farmer's level

As earlier cited, farmers do not store their produce; right after drying, seaweeds are compressed, packed in jute or nylon sacks, collected and brought to the traders' warehouses. Most farmers have some form of contractual arrangements with collectors and/or traders, as well as domestic processors. Hence, marketing schemes on price, payments, deliveries and product qualities were predetermined prior to actual production.

Some independent farmers sell freshly harvested seafood as wet seaweed. These farmers claim that the price of wet and dry seaweeds, when computed based on the price for dry seaweeds, is the same. However, the farmers who dry their produce claim that the price increment is so much higher, which gives them incentive to go through the drying process.

Traders' Level

The seaweed-trading sector has at least two "major" layers. The first layer is composed of those that move the commodity from the production site to the bigger assembly/consolidation centers. This layer of the trading sector may involve seaweed farmers, who have enough resources to provide services (and in turn obtain additional income) by purchasing the dried seaweeds directly from farmers. Some of these traders, who have enough space, would perform further drying, if and when necessary. This is performed to minimize price deductions when the seaweeds are finally brought to the bigger trading centers, such as those in Surabaya and Jakarta.

The second layer is composed of the big trading centers, which provide the link between the agar processing plants and the first level traders or sources of raw materials. Likewise, further drying is performed by these traders, if and when necessary. Seaweeds are unloaded, moisture content is determined, further cleaning is performed (e.g. removal of plastic straw, twigs, pebbles, sand, soil and other contaminants). These processes are carried out to minimize price deductions when the seaweeds are sold to the processing plants. Moreover, the big-interregional traders are the same exporters of agar and dried seaweeds as well.

Processing

Processing of agar is commercially done by factories across Indonesia but the biggest factories are found in Surabaya and Jakarta. About 22 processors are located across Indonesia, which are accessible to ports and production sites (Table 14).

Information Flow

Figure 3 describes the information flow among the players for the dried seaweed and derivatives segment. The type and quality of information exchange become more complicated as one moves down the chain. The common information among the players is price, volume or quantity of products, quality grades and class of products. However, controlling the quality of raw materials at the farm level requires a lot of efforts from the collectors and traders. In most cases, they train farmer leaders or representatives of the farming communities on the technical aspect of the seaweed trade with reference to price differences across product grades and the like. Likewise, the big/interregional traders who handle both exports of agar and dried seaweed should inform domestic traders and processors on the quality grades and international standards, including accreditation requirements.

Payment Flow

Due to the nature of seaweed production and marketing, collectors, traders (or exporters) and domestic processors usually make some form of contracts with the seaweed farmers. To avoid risks of price deduction, the full payment of the commodities are done after the assay results are available (Figure 4). Although all players prefer cash transactions, the practice of partial payments serve as hedge for poorly valued commodities. The role of mutual trust and confidence between the farmers and traders is crucial to establish strong interdependence in the process.

External Influences

1. Production and market support programs of the government

Recognizing the potential and crucial role of the seaweed industry in rural poverty alleviation and sustainable development efforts of Indonesia, the seaweed industry cluster as an agribusiness approach of controlling quality at cultivation and marketing levels within an integrated management system commenced implementation in 2008. This approach is a variant of the Nucleus Estate Management approach which was successful on the development of plantation crops. Details of the implementation concept and status of implementation are outlined in MOMAF (2011).

2. Transport services, transaction costs and availability

Transport services affect the competitiveness of seaweed value chain both directly and indirectly. Transport costs have a direct effect in that they influence the price of delivered products. However, quality of transport services regarding schedules, arrival at destination, and the frequency and reliability of service rotations (e.g., once a month, once a week, etc.) can affect the cost of maintaining large safety stocks of inventory. The complexity of shipping documentation contributes to the high transaction costs as well. For instance, there are too many certification requirements from various agencies just to ship seaweeds in Australia.

3. Socio-cultural factors as marketing constraints

Some socio-cultural factors (including citizenship, ethnicity, religion, etc.) may serve as market access constraint. For example, without a local partner, Japanese markets are extremely difficult to access due to multiple delivery documentation requirements.

Production Concerns

1. Low productivity, due to the following:
    a. incidence of “ice-ice”, characterized whitish blemish that gradually dissolves portions of the seaweed; the disease is contagious (e.g., it attacks the entire seaweed, spreading to adjacent

seaweeds, if left unchecked). Farmers quickly prune out portions that are attacked by “ice-ice” to prevent the spread of the disease.

b. practices of early harvesting of seaweeds (e.g., the seaweeds can grow to even heavier weights if left to grow for longer periods of time).

2. Increasing cost of inputs (e.g. ropes, straw lines, Styrofoam floaters, fuel for water pumps and small boat)
3. Inadequate credit access

Post-Production Concerns

1. Low quality produce due to malpractice of adding salt, sand or other debris. This is done in order to attain heavier seaweeds, which directly influences the price; however, this practice is to the detriment and disadvantage of the farmers.
2. Lack of drying facilities that could facilitate drying of cleaner seaweeds.
3. Lack of clear-cut industry-wide quality standards for dried seaweeds, hence, having no basis for determining fair prices.

General concerns

1. Increasing competition with neighboring countries such as the Philippines and Malaysia.
2. Limited technical assistance on production and post-production provided to the farmers.
3. There seems to be a “disinformation” among and between the players of the industry, especially about real value of the seaweeds at farm level and processor’s levels.

Value Chain Synthesis

The chain starts with *Gracilaria* hatcheries or seedling farms which are not well established, hence, smallholder farmers either recycle their own seedlings or source them from nearby co-farmers. Farmers employ simple implements and materials for planting seaweeds in shallow and open seas as well as in ponds.

After harvesting, farmers will dry the seaweeds along pond paddies or any available ground spaces. In some cases, farmers use drying racks. Dried seaweeds should reach a moisture content of 30-35% before marketing. Although farmers do not have any moisture tester to ascertain the moisture contents of the seaweeds, most rely on their sensory judgment.

Dried seaweeds are then compressed and packed in a 50 kg bag using a simple compressor (like a baler) before local or village-based collectors collect them. Sometimes collectors collect directly from farmers then compress and bag the seaweeds into full container lots and transport the seaweed to the port. Some intermediary collectors or agents first collect the dried seaweed directly from farmer groups or cooperatives and pass it on to another collector who bags, compresses and consolidates for full container loads before transporting the seaweeds to the port.

To expedite collection efficiency of traders and local processors, they usually put up storage or warehouses that are spread strategically across the production areas with better access to ports and transportation facilities as well. All seaweed is shipped through the ports of Surabaya and Jakarta before either being processed or exported as raw, dried seaweed. More than 90% of the processed products are exported while very little is absorbed domestically. Interestingly, however, a good number of Indonesian processors import agar and carrageenan already graded for food, pharmaceutical, industrial and energy uses.

As implied earlier, the markets for seaweed products are highly segmented and differentiated by quality, final application or use, and channel specific price discovery schemes. Hence, product pricing varies widely for what appears to be homogenous products.

At the end of the seaweed derivatives segment, where the raw materials (agar and carrageenan) are perfectly substitutable for each other, price differences depend on several factors. Mutual trust and confidence between the farm gate collectors and the seaweed farmers with respect to the uniformity of product quality must exist since results of assay will be only be available after the final sale is made. Differences in availability and charges of transport services, and differences in transaction mechanisms in terms of intermediation, dried seaweed collection, and value added/processing undertaken will also affect pricing and cost.

As one moves down the chain, knowledge content on the product sale progressively increases while the characteristics of the seaweed derivatives decline. End-users (e.g., food manufacturers) of these products buy solutions to food chemistry problems more than buying food additives. Therefore, the profit margins are wider down the chain but competition is very thin due to intellectual property rights content.

RECOMMENDATIONS

Some recommendations to address the issues and concerns are to encourage the establishment of more seaweed laboratories, nurseries or multiplier farms; establish more cluster-based post-harvest facilities; institutionalize an accreditation program for seaweed derivatives processors and manufacturers of end-products, etc.; intensify techno-transfer and capacity building; and provide capital windows to improve facilities and enhance the entire management of value chains of the seaweed industry. The goals are to sustain the implementation of the seaweed industry cluster program while promoting more private-public partnership to boost investment in the industry in general.

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Table 2. *Seaweed production in Indonesia by province.*

Rank	Province	Production volume (fresh weight in MT)			
		2007	2008	2009	Growth rate
4	Bali	152,226	170,860	135,811	-4.14%
6	West Nusa Tenggara	75,509	84,750	147,251	42.99%
2	East Nusa Tenggara	504,699	566,495	498,422	0.11%
11	South Kalimantan	6,058	6,850	1,832	-30.09%
9	East Kalimantan	17,562	19,820	7,541	-24.55%
10	North Sulawesi	4,241	4,640	7,933	40.19%
8	Gorontalo	7,117	7,790	48,280	264.61%
3	Central Sulawesi	190,073	208,040	713,562	126.22%
1	South Sulawesi	630,441	690,385	774,026	10.81%
5	Southeast Sulawesi	81,787	89,510	185,229	58.19%
7	Mollucas	16,830	37,590	47,783	75.23%
	Other provinces	41,632	58,070	395,890	310.62%
	Total	1,728,175	1,944,800	2,963,560	32.46%
	Philippines	1,505,008	1,666,497	1,739,992	7.57%

Source: Aquaculture Statistics MOMAF, 2011

Table 3. *Quantity of agarophyte imported by Japan in 1984.*

Country and region	Gelidium spp. (ton)	Gracilaria spp. (ton)
People's Republic of Korea	112	47
Taiwan	4	77
The Philippines	3	1,470
Indonesia	62	69
Chile	303	6,128
Brazil	20	607
Argentina	--	58
Madagascar	74	--
South Africa	100	895
Sri Lanka	--	45
Thailand	--	3
Vietnam	--	15
South Korea	--	48
Total	678	9,462

Source: **http://www.fao.org/docrep/field/003/AB730E/AB730E03.htm** (Training manual on *Gracilaria* culture and seaweed processing in China)

Table 4. *World production of Red Seaweed (wet, metric ton), 1999-2003.*

Country	1999	2000	2001	2002	2003	Mean	Share	Growth Rate
Philippines	673.80	679.20	761.00	884.50	985.20	796.74	31.95%	10.11%
China	426.70	494.10	599.60	687.50	740.00	589.58	23.64%	14.86%
Japan	413.10	394.50	376.30	438.60	339.50	392.40	15.73%	-3.79%
Indonesia	156.90	247.90	246.90	278.80	288.20	243.74	9.77%	18.47%
Chile	133.20	192.60	182.00	181.20	187.20	175.24	7.03%	10.49%
Korean Republic	208.60	133.40	171.70	212.60	194.90	184.24	7.39%	2.04%
Others	118.70	123.50	121.30	93.10	103.00	111.92	4.49%	-2.59%
Total	2131.0	2265.2	2458.8	2776.3	2838.0	2493.9	100.00%	7.49%

Source: FAOSTAT

__Table 5.__ Dried and processed seaweed exports from Indonesia and the Philippines.

	2000	2001	2002	2003	2004	2005	Mean	Growth rate
Indonesia								
Dried Seaweed Exports (x1000 tonnes)	22.70	27.90	28.30	39.90	51.00	69.30	43.28	18.63%
Agar and carrageenan Exports (x 1000 tonnes)	5.00	5.60	7.20	8.10	4.90	4.00	5.96	2.71%
Total Exports expressed as dried seaweed (35%MC)	40.10	43.40	43.60	57.10	64.60	87.20	59.18	10.56%
% of exports as dried seaweed	57%	64%	65%	70%	79%	79%	71%	7.03%
Value of all exports (US$$ million)	27.90	26.70	24.50	29.70	34.50	50.50	33.18	4.97%
Philippines								
Dried Seaweed Exports (x 1000 tonnes)	48.30	31.60	35.50	31.20	32.00	21.20	30.30	-6.36%
Agar and carrageenan Exports (x1000 tonnes)	7.70	8.70	7.90	10.10	12.00	9.40	9.62	10.09%
Total Exports expressed as dried seaweed (35%MC)	105.0	86.7	89.0	94.2	101.6	80.6	90.4	-0.22%
% of exports as dried seaweed	46%	36%	40%	33%	31%	26%	33%	-6.64%
Value of all exports (US$ million)	84.80	71.20	74.88	80.50	86.90	71.50	77.00	0.92%

Source: FAOSTAT

__Table 6.__ Major world producers of carrageenan (2010).

Source	**Production (MT/year)**	**Rank**	**%**
World	84,700		100.00
Philippines	34,500	1	40.73
Indonesia	17,000	2	20.07
China	9,000	3	10.63
USA	4,500	4	5.31
South America	4,500	5	5.31
France Spain	3,500	6	4.13
Denmark	3,300	7	3.90
South Korea	3,000	8	3.54
Japan	2,000	9	2.36
Malaysia	1,700	10	2.01
	1,700	11	2.01

Source: Dakay, 2010

Table 7. *Indonesian dried seaweed exports by region, 2000-2005.*

Region	2000	2001	2002	2003	2004	2005	Mean	Growth rate
China (including Hong Kong)								
Dried Seaweed Exports (x1000 tonnes)	10	9	11	17	23	33	19	19%
Value of all exports (US$ million)	4	4	5	6	7	10	6	14%
US$/tonne	350	415	412	360	291	297	355	-3%
Total Exports expressed as dried seaweed (35%MC)	12	13	17	22	25	34	22	16%
Asia Pacific (excluding China and HK)								
Dried Seaweed Exports (x1000 tonnes)	2	4	3	7	9	16	8	45%
Value of all exports (US$ million)	5	5	4	6	8	12	7	16%
US$/tonne	2300	1421	1129	824	894	744	1002	-15%
Total Exports expressed as dried seaweed (35%MC)	7	7	5	12	12	23	12	24%
Europe								
Dried Seaweed Exports (x1000 tonnes)	9	12	12	11	14	14	13	11%
Value of all exports (US$ million)	7	6	6	6	8	10	7	6%
US$/tonne	759	530	525	545	585	698	577	-4%
Total Exports expressed as dried seaweed (35%MC)	15	17	19	19	21	21	20	7%
Americas								
Dried Seaweed Exports (x1000 tonnes)	2	3	2	4	5	5	4	39%
Value of all exports (US$ million)	1	2	1	2	3	3	2	36%
US$/tonne	533	548	619	500	519	611	560	0%
Total Exports expressed as dried seaweed (35%MC)	6	5	3	4	6	7	5	11%
Africa and Mid-East								
Dried Seaweed Exports (x1000 tonnes)	0	0	0	0	0	1	0	
Value of all exports (US$ million)	0	0	0	0	0	1	0	
US$/tonne	6000	0	0	600	1000	909	502	
Total Exports expressed as dried seaweed (35%MC)	0	0	0	0	0	1	0	13%
Total								
Dried Seaweed Exports (x1000 tonnes)	23	28	28	40	51	69	43	19%
Value of all exports (US$ million)	16	17	16	20	25	36	23	11%
US$/tonne	696	615	553	513	498	512	538	-6%
Total Exports expressed as dried seaweed (35%MC)	40	43	44	57	65	87	59	11%

Source: FAO

Table 8. Indonesian agar and carrageenan exports by region.

	2000	2001	2002	2003	2004	2005	Mean	Growth rate
China (including Hong Kong)								
Agar Exports (x1000 tonnes)	1.8	2.9	4.7	3.7	1.9	1	2.8	11%
Value of exports (US$ million)	0.8	0.9	1.9	1.1	0.6	0.4	1.0	7%
US$/tonne	444	310	404	297	316	400	345.5	-4%
Carrageenan Exports (x1000 tonnes)	0.2	0.06	0.2	0.5	0.4	0.04	0.2	59%
Value of exports (US$ million)	0.1	0.04	0.05	0.3	0.3	0.1	0.2	93%
US$/tonne	500	667	250	600	750	2500	953.3	27%
Asia Pacific (excluding China and HK)								
Agar Exports (x1000 tonnes)	0.6	0.5	0.2	0.5	0.5	0.8	0.5	15%
Value of exports (US$ million)	1.7	2	1.3	1.5	1.9	4.9	2.3	5%
US$/tonne	2833	4000	6500	3000	3800	6125	4685	15%
Carrageenan Exports (x1000 tonnes)	0.2	0.4	0.1	0.5	0.3	0.5	0.4	77%
Value of exports (US$ million)	0.2	0.2	0.06	0.8	0.3	1.7	0.6	220%
US$/tonne	1000	500	600	1600	1000	3400	1420	20%
Europe								
Agar Exports (x1000 tonnes)	1	0.8	1.1	1	0.9	0.7	0.9	0%
Value of exports (US$ million)	4.5	2.9	3.3	3.3	3.3	2.9	3.1	-4%
US$/tonne	4500	3625	3000	3300	3667	4143	3547	-3%
Carrageenan Exports (000 tonnes)	0.2	0.2	0.5	1.4	0.6	0.7	0.7	55%
Value of exports (US$ million)	0.5	0.8	1.5	1.7	1.8	4.1	2.0	33%
US$/tonne	2500	4000	3000	1214	3000	5857	3414	25%
Americas								
Agar Exports (x1000 tonnes)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	-10%
Value of exports (US$ million)	0.6	0.4	0.4	0.4	0.4	0.6	0.4	-7%
US$/tonne	3000	2000	4000	4000	4000	6000	4000	13%
Carrageenan Exports (x1000 tonnes)	0.7	0.3	0	0	0.1	0.03	0.1	
Value of exports (US$ million)	3.7	1.4	0	0	0.6	0.2	0.4	
US$/tonne	5286	4667	0.00	0.00	6000	6667	3467	
Total								
Agar Exports (x1000 tonnes)	3.7	4.5	6.2	5.6	3.5	2.7	4.5	2%
Value of exports (US$ million)	7.7	6.3	7.7	6.5	6.23	8.85	7.1	-3%
US$/tonne	2081	1400	1242	1161	1780	3278	1772	1%
Carrageenan Exports (x1000 tonnes)	1.3	0.96	0.86	2.43	1.4	1.28	1.4	21%
Value of exports (US$ million)	4.5	2.44	1.61	2.8	3	6.1	3.2	0%
US$/tonne	3462	2542	1872	1153	2143	4766	2495	-1%

Source: FAO

Table 9. Export volume and value of Indonesian seaweeds.

Commodities	2007			2008			2009		
	Volume (kg)	Value (US$)	Unit value	Volume (kg)	Value (US$)	Unit value	Volume (kg)	Value (US$)	Unit value
Seaweed (dried)	94,073,398	57,522,350	0.61	99,948,576	110,153,291	1.10	94,002,964	87,773,297	0.93
Gelatin/agar	2,117,712	9,436,751	4.46	2,467,355	14,206,160	5.76	1,794,858	10,309,814	5.74
Total		66,959,101			124,359,451			98,083,111	

Source: Fisheries Trade Statistics, MOMAF, 2010

Table 10. Seaweed derivatives and selling prices, Indonesia.

Price	*Cottonii*		*Gracilaria*	
	IDR/kg	US$/tonne	IDR/kg	US$/tonne
Farm gate (assorted)	4,500.00	500.00	3,500.00	389.00
Dried Seaweeds::				
Class A			10,000.00	1,111.11
Class B			6,000.00	666.67
Class C			5,000.00	555.56
Processed (carrageenan) grades:				
ATC		2,700.00		
SRC Technical grade		3,750.00		
SRC food grade		6,500.00		
Clarified RC		10,000.00		
Processed (agar) grades:				
Agar food grade		not available		
Blended food additives		16,500.00		

Exchange rate: US$1:IDR 9,000.00

Source: Based on personal communications with key informants.

Table 11. *Cost of shipping dried and processed seaweed products.*

Product	Sulawesi to Surabaya/Jakarta	Indonesia to	
		China	Europe
Pressed dried seaweed (20 tonne/container)	IDR540/kg	not available	not available
Not pressed dried seaweed (12 tonne/container)	IDR430/kg		
Processed powder (21 tonne container capacity)		IDR 900/kg	IDR 1200/kg
Processed chips (12 tonne container caapacity)		IDR 1600/kg	IDR 2000/kg

Exchange rate: US$1:IDR 9,000.00

Table 12. *Gross margins of dried Gracilaria across product class (per kilogram).*

	Assorted		Class A		Class B		Class C	
Particular	IDR/kg	US$/kg	IDR/kg	US$/kg	IDR/kg	US$/kg	IDR/kg	US$/kg
Farm gate price of dried gracilaria	4,500.00	0.50	10,000.00	1.11	6,000.00	0.67	5,000.00	0.56
Cost of production								
Seedlings	1,500.00	0.17	1,500.00	0.17	1,500.00	0.17	1,500.00	0.17
Other major inputs	1,800.00	0.20	1,800.00	0.20	1,800.00	0.20	1,800.00	0.20
Shipping cost for pressed dried gracilaria	540.00	0.06	540.00	0.06	540.00	0.06	540.00	0.06
Total cost	3,840.00	0.43	3,840.00	0.43	3,840.00	0.43	3,840.00	0.43
Gross margin	660.00	0.07	6,160.00	0.68	2,160.00	0.24	1,160.00	0.13

Exchange rate: US$1:IDR 9,000.00
Based on personal communication with key informants (2012).

Table 13. *Indonesian seaweed processors.*

Company	Factory Location	Product type	Capacity (metric ton/year)			
			Rated	RM Needed	Actual	RM Needed
Pt. Galic Artha Bahari	Cikarang	ATC & SRC	2,040	8,568	1,224	5,141
Pt. Gumindo Perkasa Industri	Banten	SRC Food grade	1,200	6,000	720	3,600
Pt. Giwang Cintra Laut	Takalar	ATC & SRC	960	4,032	576	2,419
Pt. Cahaya Cemerlang	Makasar	ATC & SRC	720	3,024	432	1,812
Pt. Bantimurung Indah	Makasar	ATC & SRC	3,000	12,600	1,800	7,560
Primkopin	Janeponto, Sulsel	ATC	720	2,880	-	-
Pt. Algalindo Perdana	Pasuruan	RC	1,560	7,956	936	4,774
Pt. Centram Pasuruan	Pasuruan	RC	432	6,480	259	3,888
Pt. Indonusa Algaenas Prima	Malang	ATCC	4,800	19,200	2,880	10,520
Pt. Amarta Carragenan	Gempol & Pasuruan	SRC	480	7,800	288	8,640
Pt. Azwa Utama	Gorontalo	ATC	360	1,440	216	864
Pt. Langit Laut Biru	Maumere-NTT	ATC	180	720	108	432
Pt. Algae Sumba Timur	Waingapu-Sumba Timur-NTT	ATC	2,160	8,640	1,296	5,184
Pt. Agar Swallow	Citerep-Bogor	Agar	480	2,880	288	1,728
Pt Agarindo Bogatama	Tangerang	Agar	3,000	18,000	1,800	10,800
Pt. Surya Indo Algas	Jimbaran Wetan	Agar	240	1,440	144	864
PT. Satelit Sriti	Surabaya	Agar	480	2,880	288	1,728
CV. AGAR Sari jaya	Malang	Agar	240	1,440	144	864
PT. Samudera Agar Indonesia	Solo	Agar	360	2,160	216	1,296
PT. Indoking Aneka Agar-agar	Medan	Agar	360	2,160	216	1,296
PT. Biliton Sejahtera Mandiri	Balitung	ATCC	360	2,160	216	1,296
PT. Phonix Mas	Mataram	Agar	240	3,600	144	2,160
TOTAL			24,372	126,060	14,191	76,866

Source: Aquaculture Statistics MOMAF, 2011

Table 14. *Indonesian importers of seaweed derivatives.*

Company	Location	Product type
PT. Galic Bina Mada	Cikarang Barat Bekasi	Carrageenan
PT. Frisian Flag	Jakarta Timur	Carrageenan
PT. Halim Sakti Pratama	Jakarta Indonesia	Carrageenan
PT. Lion Wings	Jakarta Timur	Carrageenan
PT. Sinar Permata Halim Swadaya	Surabaya	Carrageenan
PT. Ki Antaka Rasa	Tangerang	Carrageenan
PT. Nestle Indonesia	Jakarta Indonesia	Carrageenan
PT. Behn Meyer Kimia	Tangerang	Carrageenan
PT. Satelit Sriti	Surabaya	Carrageenan
PT. Multi Kimia Inti Pelangi	Cikarang Barat Bekasi	Carrageenan
PT. Centram	Pasuruan Jawa Timur	Carrageenan
PT. Brataco	Bandung Jawa Barat	Carrageenan
PT. Galic Arthabahari	Cibitung Bekasi	Carrageenan
PT. Pafa Mandiri Sakti	Jakarta Barat	Carrageenan
PT. Alvia Tri Mandiri	Jakarta Barat	Carrageenan
PT. Agar Sehat Makmur Lestari	Pasuruan	Agar-agar
CV. Sinar Kejayaan Brothers	Sungai	Agar-agar
PT. Segera Jaya Perkasa	Jakarta Utara	Agar-agar
PT. Buana Jaya Perkasa	Jakarta Utara	Agar-agar
PT. Petrona Inti Chemindo	Cengkareng Barat	Agar-agar
PT. Alam Subur Tirta Kencana	Jakarta Barat	Agar-agar
PT. Merck TBK	Jakarta Timur	Agar-agar
PT. Trimulti Maha Barata	Tanjung Priok	Agar-agar
PT. Sari Coffee Indonesia	Karet, Tengsin, Tanah Abwisma	Agar-agar
CV. Anugerah Jaya Abadi	Jakarta Barat	Agar-agar
CV. Agar Sari Jaya	Pasuruan	Agar-agar
PT. Petrakemindo Pratama Mandiri	Cipandah	Agar-agar
PT. Sindo Makmur Sentosa	Nagoya Centre Block 8 Batam	Agar-agar
PT. Abilindo Lintas Persada	Jakarta Utara	Agar-agar
CV. Inti Karya Cemerlang	Jakarta Barat	Agar-agar
mur Sentosa	Jaksel	Agar-agar
PT. Agarindo Bogatama	Jakarta	Agar-agar
PT. Chitra Adhi Perkasa	Graha Samudera	Agar-agar
PT. Catur Harapan	Batam	Agar-agar
PT. Exim Tuna Indonesia	Pluit	Agar-agar
PT. Aneka Tuna Indonesia	Jawa Timur	Agar-agar
PT. Sindo Makmur Sentosa	Batam	Agar-agar
PT. Rajawali Prima Sakti	KEL	Agar-agar

Source: Aquaculture Statistics MOMAF, 2011

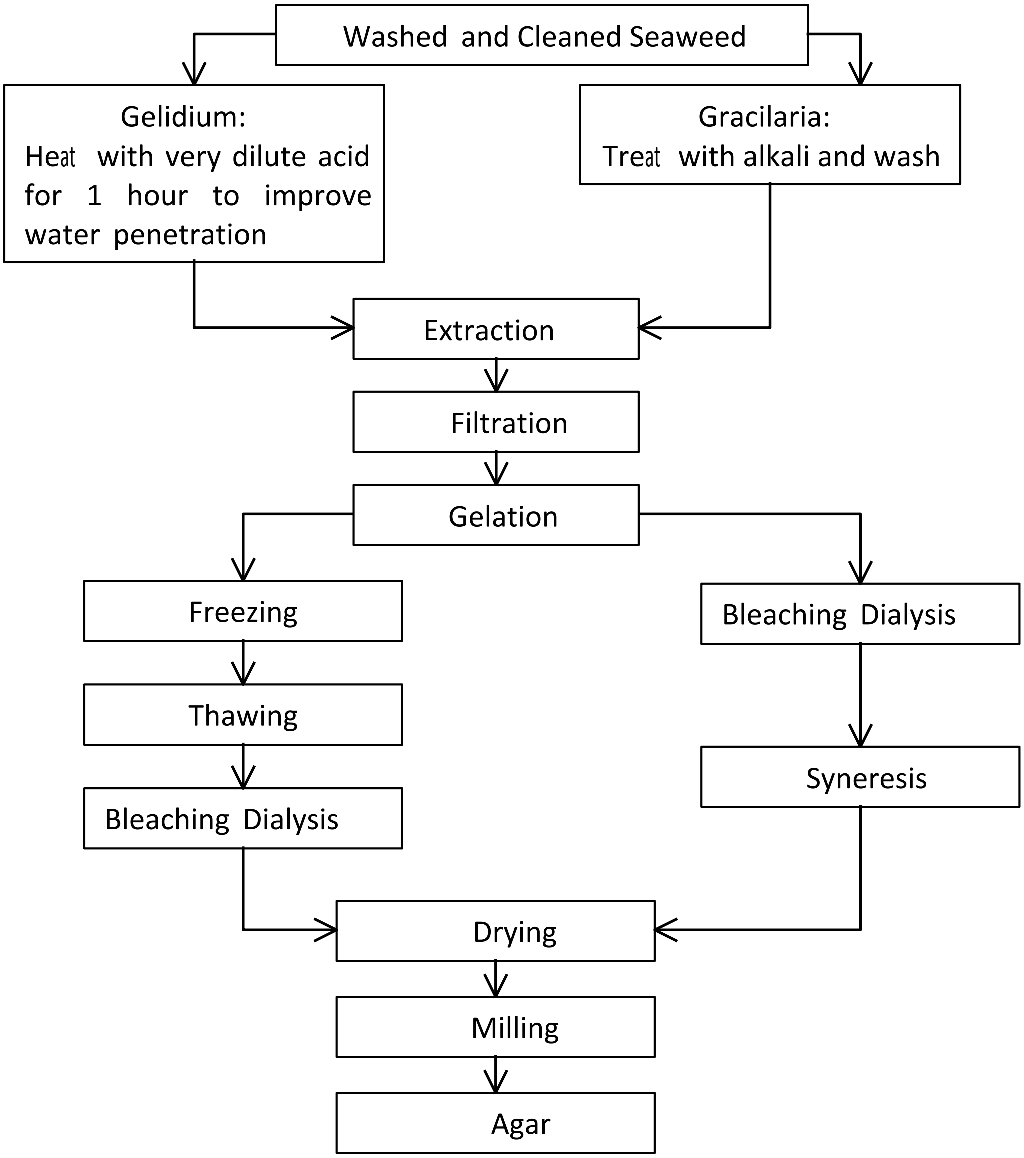

Figure 1. *Agar production process flow*

Figure 2. *Value chain key players and product flow*

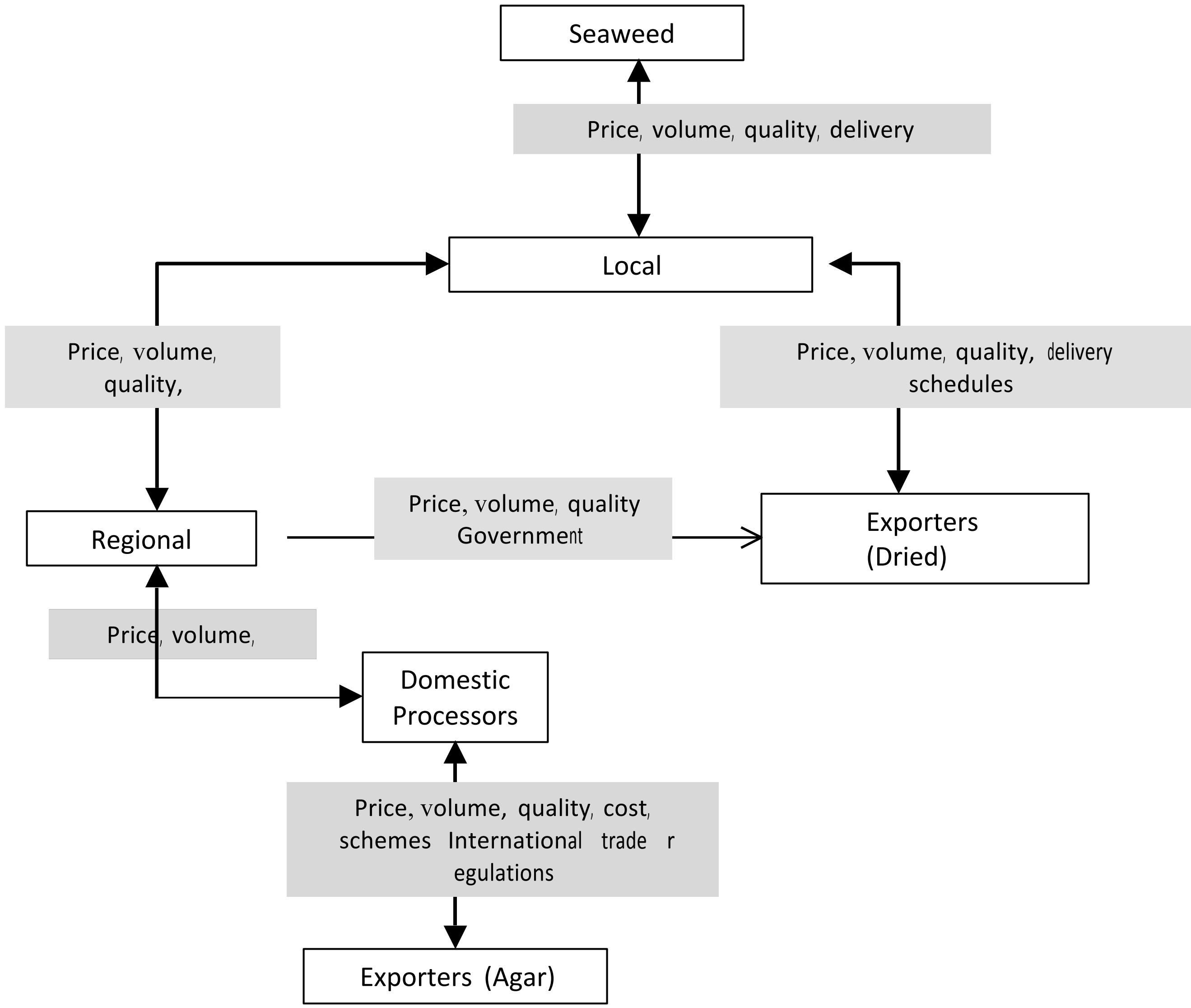

Figure 3. *Information Flow*

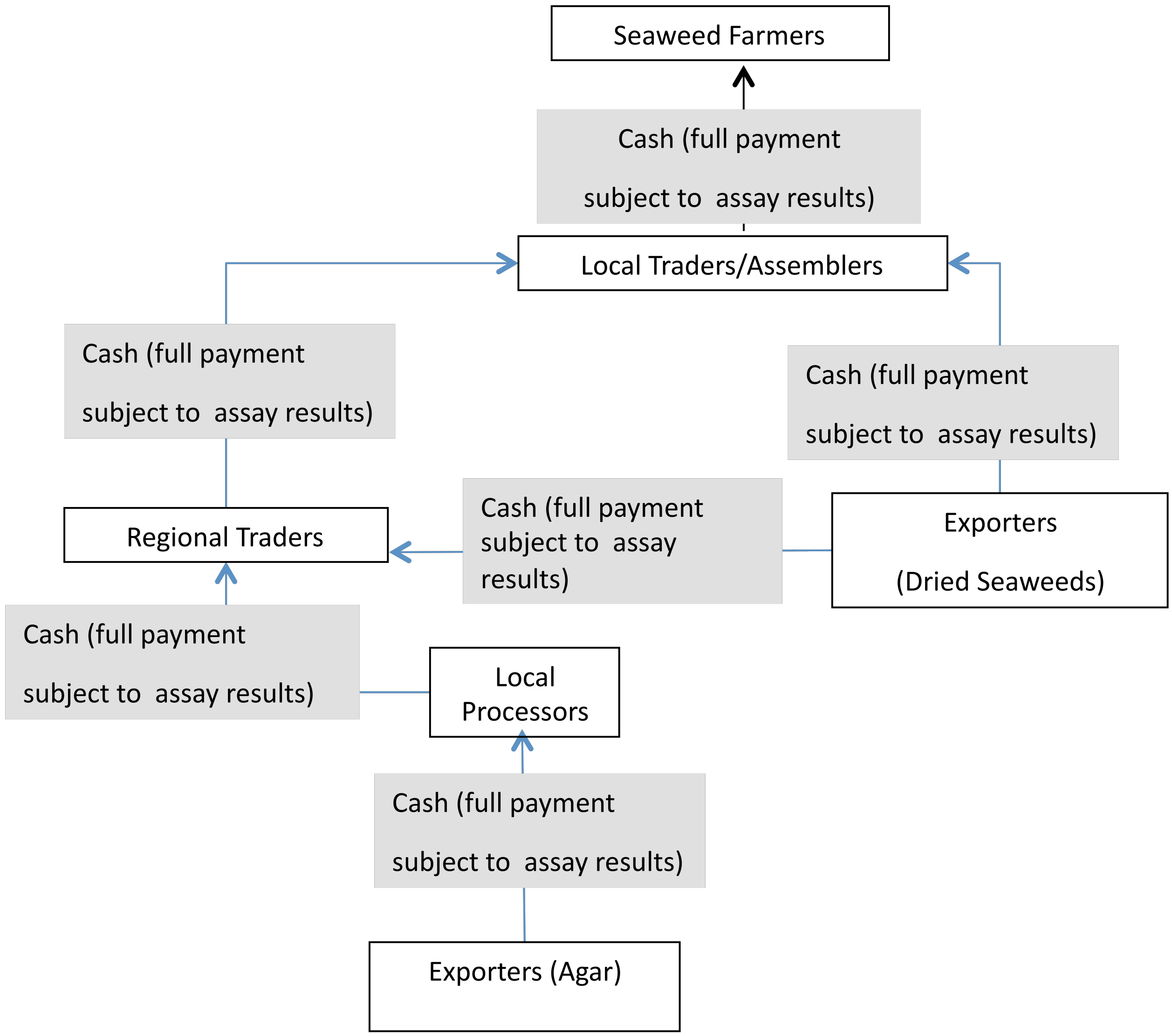

Figure 4. *Payment Flow*

TOPIC AREA:
VALUE CHAIN ANALYSIS

❖

ASSESSMENT OF TILAPIA VALUE CHAIN IN GHANA

Marketing, Economic Risk Assessment & Trade/Study/09MER07PU

FINAL INVESTIGATION REPORT

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ABSTRACT

The performance of farmed tilapia value chain in Ghana can be used to achieve sustainable food production and poverty alleviation through improvements in market access and competitiveness. The study was conducted to assess the value chain of farmed tilapia in Ghana; specifically, characterize the current farmed tilapia value chain, analyze the performance, identify areas of improvement, and provide recommendations for strategic improvement of the value chain. Data was collected from a survey conducted in 2012. Key actors in the tilapia value chain in Ghana were identified, and information was obtained on their activities and roles, the flow of products and information, costs and margins, and external influences. The key chain actors identified were input suppliers (brood stock developers and hatcheries, feed suppliers, pond and cage constructors, and net suppliers); producers (pond and cage grow-out farmers); processors; marketers (distributors and retailers); and food services (restaurants, food vendors, etc.). A Benefit-Cost Analysis was used to assess the performance of input suppliers, fish farmers, marketers, and food services. The results revealed that all chain participants had a benefit-cost ratio higher than 1 except fish farmers, suggesting that fish farming is less profitable compared with the other value chain activities. Input suppliers appeared to make the most profit. The study also used Factor Evaluation Matrix to compare the competitiveness of the different value chain participants in terms of the traditional five marketing factors, i.e., product, place, price, promotion and procurement (process). Input suppliers also had the highest self-evaluation performance in terms of Porters' 5 forces framework and had the strongest sector in the value chain. The success of input suppliers in the value chain may be attributed to their efficiency in terms of having well defined payment transactions with customers, having persistent relationships with customers, and keeping good records of costs and revenues. Other chain actors could form strong persistent linkages among themselves to improve the relationships among actors and ensure efficiency in the value chain. Fish farmers could also prioritize record keeping of costs and revenues to enable them to track their performance in terms of profit margins. To ensure quality products and services are supplied along the chain, the Fisheries Directorate of Ghana should consider setting and enforcing quality standards along the chain, especially for hatcheries and processors.

INTRODUCTION

Aquaculture production has the potential to contribute to alleviating hunger and poverty in Sub-Saharan Africa (Kaliba et al., 2007). Ghana has made tremendous improvements in the aquaculture industry with large commercial production of tilapia (*Oreochromis niloticus*) from cage culture and the traditional earthen pond culture. The aquaculture industry in Ghana has therefore demonstrated improvements in competitiveness, producing tilapia species that feed low on the food chain in well adapted, environmentally friendly, and profitable farming systems.

The performance of tilapia value chain in Ghana can be used to achieve sustainable food production and poverty alleviation through improvements in market access and competitiveness. For example, smallholder fish farmers through linkages among the different stakeholders such as the input suppliers, processors, traders, and other retailers can manage the flow of goods and services to enhance their economic wellbeing (Christiaensen et al. 2011). Proper linkages could result in increased productivity and efficiency and provide access to new markets. Value-chain linkages improve information flow and learning capacities and also help to reduce transaction costs (Trienekens, 2011). Improved value chain increases productivity in terms of value and profitability, which in turn could generate increased incomes in a sustainable manner. Value chain collaboration then becomes very important for smallholder producers in developing countries to ensure access to new and profitable markets.

The objectives of this study are to:
1. Characterize current tilapia value chain in Ghana
2. Analyze tilapia value chain performance in terms of cost-benefits comparisons
3. Identify areas for improvement in value chain
4. Provide recommendations for strategic improvements and long term sustainability

Study Areas

Data from previous studies in Ghana show that aquaculture is concentrated in five major regions: Ashanti, Brong Ahafo, Western, Eastern, and Volta regions (Anane-Taabeah, 2012). Cage aquaculture is predominant in the Eastern and Volta regions, whereas the other three regions are predominantly pond-based aquaculture. This study therefore covers these five regions to provide an overview of the farmed tilapia value chain in Ghana.

Data Collection

Secondary data collection
Secondary data from the Department of Fisheries and Watershed Management, KNUST, and interaction with relevant stakeholders revealed that the farmed tilapia value chain involved five key chain actors: those who supplied inputs such as fingerlings and feed to farmers; fish farmers; processors; traders; and food services. Information was also obtained about the major market centers for farmed tilapia, as well as contacts and locations of other key value chain actors in Ghana.

Primary data collection
The primary data was collected in two phases using surveys. The first stage involved surveying fish farmers from the Ashanti, Brong Ahafo, and Western regions who participated in a national workshop on pond aquaculture best management practices. The second stage involved surveying cage farmers in the Eastern and Volta regions, and the other key actors in the value chain, including input suppliers, fish marketers, and food services.

Questionnaire design
Five survey questionnaires were designed for the actors identified as key players in the tilapia value chain in Ghana. The questionnaires were previously developed for a similar study in Kenya involving women in aquaculture. The first few questionnaires administered for each group were pretested with a small sample

of actors. Their responses were then used to modify the final versions of the survey instruments accordingly. The questionnaires were designed to obtain the following information:

1. Key players and their major activities
2. Major routes of products
3. Information flow
4. Payment flow
5. Value chain performance using Cost Benefit Analysis, SWOT analysis and other metrics

Data and Information Analysis

Flow chart analysis and supply chain maps were used to characterize the farmed tilapia value chain in terms of the key players and their major activities, product flow, information flow, and payment flow. Descriptive statistics, and qualitative and quantitative analyses were used to assess the performance of the value chain.

Characterization Of The Farmed Tilapia Value Chain In Ghana

Key players and their activities

A Value Chain Analysis (VCA) map plots the flow of goods and services in the chain to illustrate how behavior plays a role in success (Kaplinsky & Morris, 2000). The maps provide information on specific activities and services at each stage of the chain, key players, flow of product and information, nature of transactions among stages of the chain/actors, and other external influences to the chain performance (Humphrey, 2005; Jamandre et al., 2011).

The key chain actors identified in the farmed tilapia value chain in Ghana were input suppliers; producers; processors; traders and food services. The total number of respondents surveyed in the study is presented in Table 1. The key chain actors and a summary of their major activities are presented in Figure 1.

Table 1. *Number of survey respondents in the tilapia value chain.*

Key players	Number of respondents
Input suppliers	19
Producers	93
Processors[1]	2
Wholesalers/distributors[2]	5
Retailers[2]	53
Food services[2]	46

[1] The processors surveyed were members of a particular group but they provided responses representative of the activities of other groups.

[2] Of the number presented for retailers, 6 traded only farmed tilapia, whereas 47 traded both farmed and wild tilapia, and 2 did not know the origin of the fish. For the food services, 29 purchased only farmed tilapia, and 17 purchased both farmed and wild tilapia.

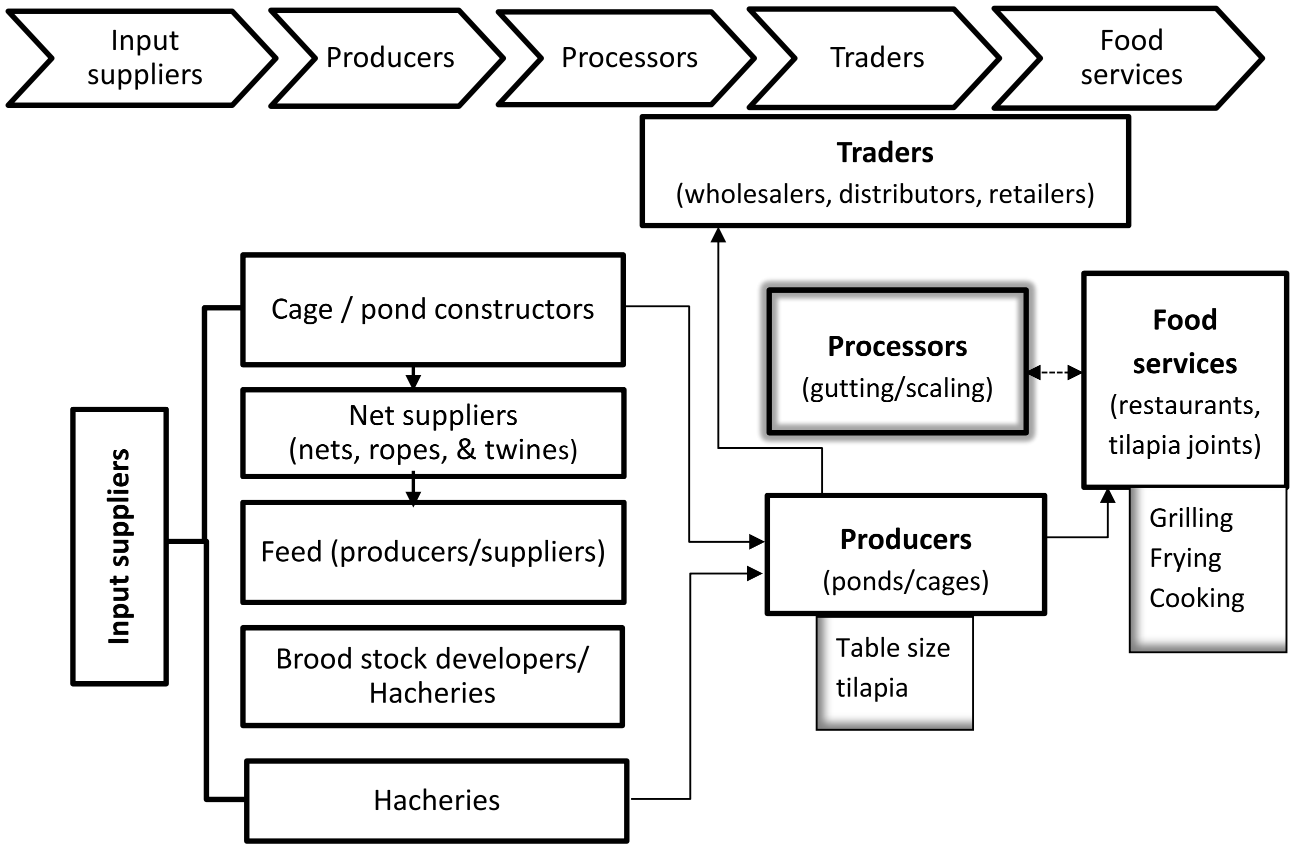

Figure 1. *Key players and their major activities.*

Input suppliers

The input suppliers consist of brood stock developers (who also sell fingerlings), fingerlings producers (hatcheries), feed producers/suppliers, pond and cage constructors, and net suppliers. Input suppliers market their products and services mostly through delivery and/or wholesale and retail outlets. Apart from the net suppliers whose primary target market are fishermen, fish farmers are the primary target markets for all the input suppliers. With the exception of the brood stock developers and hatcheries, which are a mixture of government and private businesses, all other input suppliers are private individuals and organizations. The majority of the feed producers and suppliers are relatively newer to the aquaculture business compared to the other input suppliers. Over 85% of the feed suppliers started their business within the last couple of years. The input suppliers are optimally located in four regions: Ashanti, Brong Ahafo, Eastern, and Greater Accra regions, close to where major aquaculture operations are situated.

The pond and cage construction business is composed of individual businesses as well as group or cooperate businesses. The pond constructors have been in the business longer than cage constructors, which is expected considering that cage aquaculture is relatively new in Ghana compared to earthen pond aquaculture. For a pond of about 300m^2, it takes a single individual about 1 month to complete a manual construction. Mechanical excavators can reportedly do the same job in a relatively shorter time. For cages, it takes about 3 weeks for an individual to construct a 25m^2 fish cage. Both pond and cage constructors were located close to ‘hot’ spots of aquaculture. The pond constructors identified in this study are located in the Ashanti, Brong Ahafo, and Western regions, even though we were only able to survey those in the Ashanti and Brong Ahafo regions. The cage constructors were located in the Eastern region, specifically, in the Asuogyaman district, where majority of cage farming operations are situated.

Commercial net supply to fish farmers is still a burgeoning business depending heavily on the development of cage aquaculture, since most earthen pond farmers use few nets. Net suppliers retail imported products such as nets, ropes, and twine mostly from Korea and Vietnam.

Only one feed supplier produces fish feed locally. All other suppliers import fish feed mainly from Brazil, Netherlands, and United States. The fish feed suppliers provide feed suitable for use by brood stock developers, hatcheries, and fish producers.

Both the brood stock developers and the hatcheries provide aquaculture training and general technical advice to farmers and the public. Depending on the nature of training and duration, these services could be free or attract fees. Some large scale fish producers develop brood stock and produce fingerlings but only for their own use. Only one commercial brood stock developer was encountered during the study, who also supplied fingerlings to farmers. The majority of the hatcheries produce and supply sex-reversed tilapia fingerlings of about 5g to farmers. However, the supply of 2g fingerlings, especially to cage fish producers, is common since demand is high and it takes about 7 to 8 weeks to obtain 5g of sex-reversed fingerlings. Typically, farmers have to place orders for fingerlings, and depending on the size of orders, it can take weeks to have their orders fulfilled. Since the major brood stock developer is responsible for producing and supplying the improved 'Akosombo' strain of the Nile tilapia to hatcheries across the country, it can be assumed that the 'Akosombo' strain of the Nile tilapia is the major strain cultured in Ghana.

Producers
Two primary categories of producers were identified; pond and cage grow-out farmers. However, a few cage farmers also operate ponds. Cage farmers produce only tilapia, whereas some pond farmers culture additional species such as *Clarias sp*, *Heterotis niloticus*, and *Parachanna obscura*.

Cage farmers are characterized by intensive production and may be grouped into small scale (< 10 cages), medium scale (10 to 50 cages), and large scale (> 50 cages) operations. Pond and cage grow-out farmers focus on producing table size tilapia for sale to traders, food service providers, and final consumers. Some grow-out tilapia producers also double as hatcheries, marketing fingerlings to fellow grow-out farmers. It usually takes cage farmers about 6 months to grow fish to obtain 2-3 pieces of fish per kg. However, pond farmers may obtain 4-5 pieces per kg for the same period of time. The difference in productivity can be attributed to a number of factors. Cage farmers grow sex-reversed fingerlings and though 100% all male fingerlings are presently not attained in Ghana, the cage environment does not support prolific breeding of tilapia. Conversely, pond farmers use both mixed and sex-reversed tilapia and have problems such as overpopulation and reduced growth in their ponds. Whereas cage farmers use high quality commercial fish feed, only a limited number of pond farmers consistently use commercial feed because of capital constraints. Cage farmers have relatively shorter and specialized marketing channels compared to pond farmers. Ninety-five percent of the cage farmers surveyed sold their fish exclusively at the farm gate and mostly to retailers, whereas many pond farmers have varying customer types and only about 31% sold exclusively at the farm. Thus, cage farmers may have higher efficiency than pond farmers because of the reduced transaction cost in their marketing.

Processors
Farmed tilapia is mostly marketed fresh compared to wild tilapia, which may be smoked, dried, or salted. There appears to be no demand for live fish in Ghana. Thus, processors of farmed fish, who are predominantly women, are engaged mainly in gutting and scaling of the fish. The processors are central to the value chain because, apart from the input supplies, they interact with all key actors in the value chain. Even though they do not purchase the fish themselves, they provide ready services to traders, food service providers, and consumers at the point of sale of the fish. Gutting is usually done on the farm for a fee. Scaling may be done together with gutting if the buyers are food service providers or consumers.

Otherwise, the service is usually offered at distribution points or sales outlets. These processors may be local residents around farms and sales outlets or may commute to such places to offer their services. They are mostly individuals accountable to themselves but may work in a group. A group of 10 female processors is not uncommon and one can observe up to 4 of such groups at Galilea market, a busy tilapia (both wild and farmed) sales outlet close to Kasoa in the Central Region.

Traders
Marketing of farmed tilapia occurs through three key traders: wholesalers (who may also retail), distributors, and retailers. Wholesalers buy large quantities of fish. Some tilapia producers also wholesale their fish at sales points. Wholesalers sell at a designated location in owned or rented stores. Typical wholesalers supply fish to both distributors and retailers, and are usually the traders who deal directly with the farmers. Distributors typically sell smaller quantities of tilapia compared to wholesalers and usually deliver to retailers, sell at cold stores, or deliver to restaurants. Retailers trade in small quantities of tilapia and usually sell in the community markets directly to consumers. Retailers sell in stalls (owned or rented), on table tops, or in pans. Some retailers also hawk their wares as a means of increasing sales. The main value addition performed by all the traders is packaging and facilitation of product movement from supply centers to demand centers. However, retailers also scale fish free of charge to customers as a strategy to increase sales. Customers may also obtain limited free ice from wholesalers, distributors, or retailers to preserve their fish.

Foods services
Food services identified were restaurants, tilapia 'joint' operators, and 'chop bar' operators. A supermarket was identified that traded in both frozen and processed (grilled) farmed tilapia, but they were not available for the survey.

Restaurants are either standalone entities or within hotels. Most restaurants perform a variety of value addition activities including cleaning, dressing, and seasoning. All the restaurants surveyed had grilled tilapia and 'banku' on their menus, while some also had boiled tilapia served in soup. The restaurants are noted for requiring large size tilapia (400g and above) because of their customer base. Consequently, cage farmers tend to have an advantage when their target market is restaurants compared to pond farmers.

The tilapia 'joint' operators are the individuals or groups that specialize in grilling tilapia. The grilled tilapia is usually sold with 'banku' and has a reputation of being a luxury meal for the middle income group. Tilapia 'joints' may be found at roadsides of busy towns and operate typically between 1600hrs and 2300hrs. Tilapia 'joints' are increasingly being situated near pubs and drinking bars to take advantage of the customers that frequent there.

Compared to restaurants and tilapia 'joints,' 'chop bars' are affordable eating places where one can purchase cheap tilapia. Most 'chop bars' are noted for their wide range of local Ghanaian dishes. Thus, most 'chop bar' operators tend to boil or steam tilapia in contrast to grilled tilapia.

Product flow
The major supply centers for inputs in the value chain are the Ashanti, Brong Ahafo, Eastern, and Greater Accra regions. The inputs are supplied across the entire country to producers but fish production activities are concentrated within the Western, Brong Ahafo, Ashanti, Eastern, and Volta regions. The majority of the marketable fish produced in the Western, Brong Ahafo, and Ashanti regions are consumed within these regions. Since these regions are predominantly pond-based aquaculture, it is possible that the quantity of fish produced is not enough to allow export outside these regions.

In the Eastern and Volta regions, where cage aquaculture has a strong presence, production volumes are significantly higher than the other major supply centers. Within the Eastern region, the town of

Akosombo is a major demand center. Other demand centers in the Eastern region include Akuse and Asutsuare. Interestingly, the bulk of fish produced within the Eastern and Volta regions are sold outside of those regions. This is because some farmers have wholesale and distribution points within the Greater Accra region where demand for 'banku' and tilapia is relatively high. Specifically, Accra, Tema, and Ashaiman, which are major metropolitan areas, are the major demand centers within the Greater Accra region. Kasoa in the Central region is another important demand center for fish from the Eastern and Volta regions. The presence of a vibrant market for fresh tilapia at Kasoa has attracted farmers and wholesalers alike to this demand center where distributors, retailers, and consumers converge to transact business. Figure 2 shows the major supply and demand centers of products in the value chain.

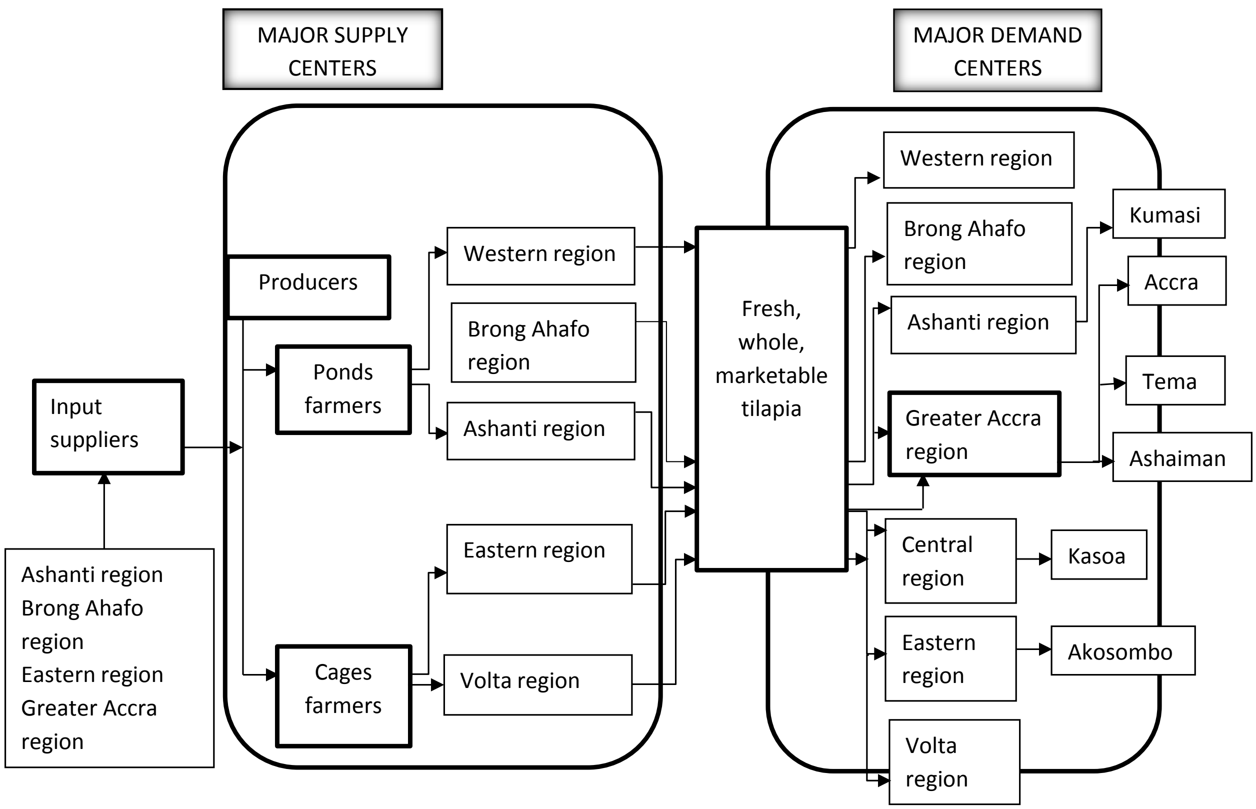

Figure 2*. Major routes of the tilapia value chain.*

Payment flow

Payment for products and services along the value chain is mostly cash and carry or cash in advance of service. Payment flexibility such as buying on credit for a few days and doing business on contractual basis exists among a few chain actors that have well defined trust relationships. Figure 3 shows the major payments transaction modes existing among chain actors.

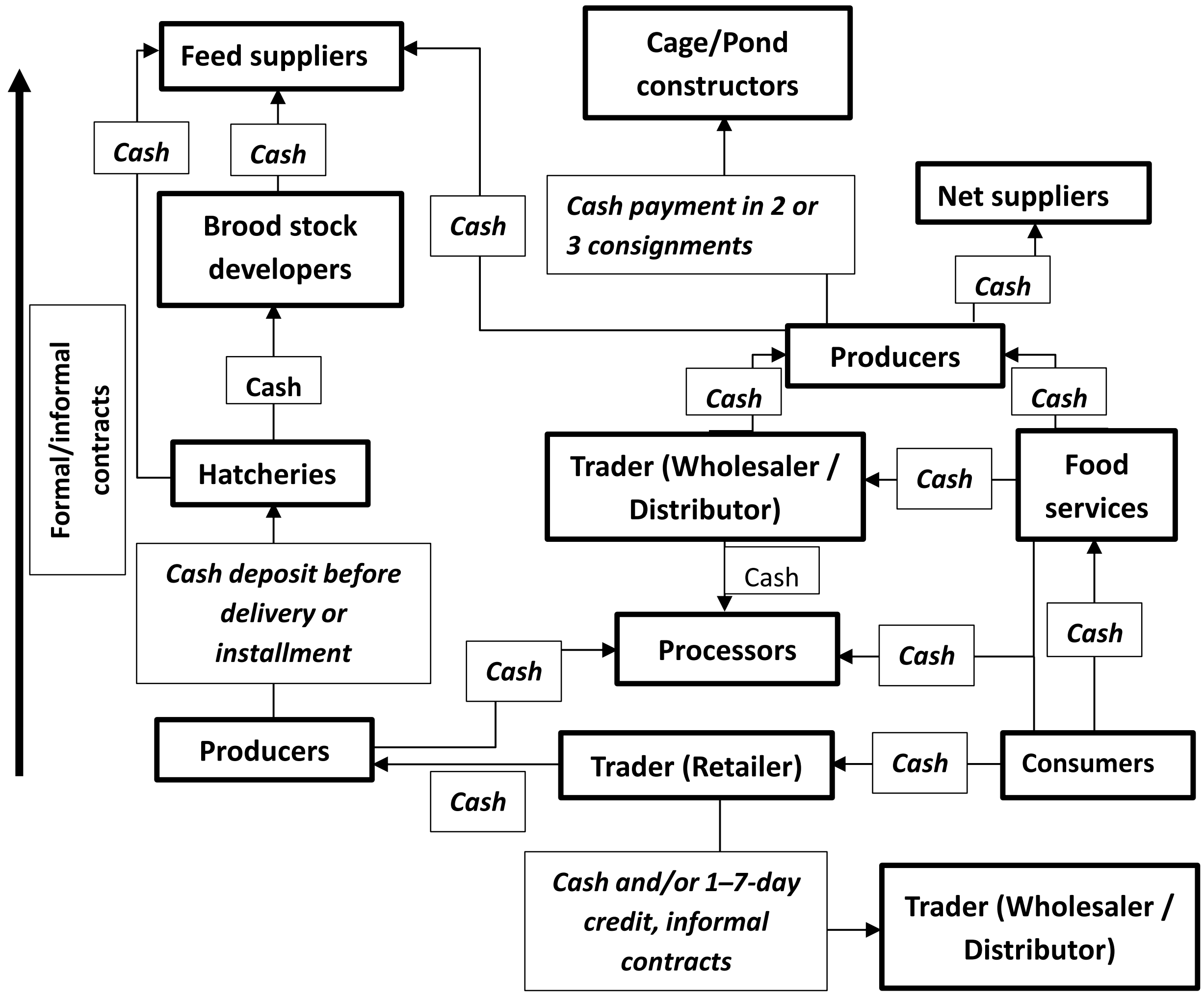

Figure 3. *Payment transactions in the tilapia value chain.*

Information flow

Figure 4 provides a description of information flow among the key actors in the tilapia value chain. Face-to-face interaction and mobile phone use are the primary means of communication between key actors in the value chain. The major information required by key actors is prices, quality, sizes, availability, and sources.

Prices of inputs are generally unstable due to the fluctuations of the local currency to the American dollar. In recent months where the cedi has seen constant depreciation, producers had to contend with high prices of imported feeds. However, unlike traders, the majority of whom use cost plus to determine their prices, farmers face the unpleasant situation of maintaining marginal profits.

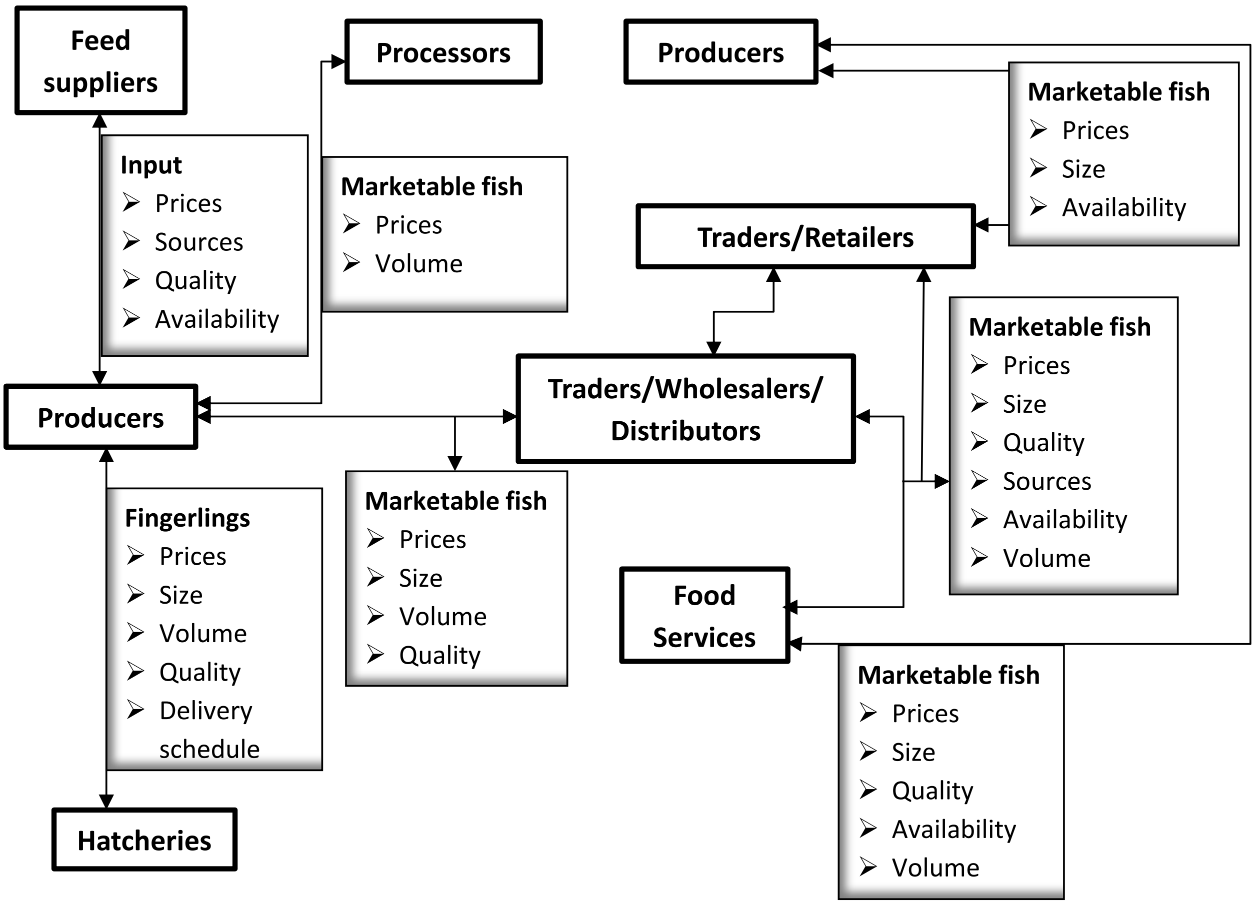

Figure 4. *Information flow among the key actors in the tilapia value chain.*

Quality of inputs such as feed and fingerlings are essential to produce quality marketable fish. Feed is the single most expensive input and suppliers have to ensure that quality feed is available to farmers for the production of marketable-size fish. Quality feed helps fish to attain market sizes in the shortest possible time. For traders, the ability to convince customers of the freshness and quality is central to their sale success.

Size requirements are important to everyone in the value chain. For instance, feed sellers supply feed of specific sizes for different stages in the growth of the fish and must ensure that the required sizes are available. For the producers, the appropriate fingerling sizes would determine the production duration and wellbeing of the fish. With increasing demand for fingerlings, especially among cage farmers, producers often have to settle for smaller size (2 g) fingerlings. The costs incurred under such conditions include higher cost of feeding and/or mortalities. Wholesalers, retailers, and the food service sector all have their size requirements for the fish and they furnish the producers with that information before fish is supplied.

Availability and quantity of products that can be supplied are essential for efficiency in the value chain. When feed suppliers and hatcheries renege on supply agreements, the entire chain is affected. For instance, traders are affected when producers are unable to provide the desired quantities of fish and may result in trading in wild fish, which affects the aquaculture industry.

The source of products is tied closely to quality and greatly influences the flow of products in the value chain. An important consideration is that of the type of fish, whether farmed or wild caught. Some distributors and retailers are indifferent to the source of the fish. However, others consider the source of the fish because their customers demand it. Taste, texture, price, and availability are four important factors that were found to affect the choices traders and food services made regarding source. Some opined that wild fish were tastier, more available, and firmer than farmed fish, thus they only traded in wild fish. Price apparently favored farmed fish. Nonetheless, farmed fish face some marketing challenges because of rumors that farmed fish are boosted with chemicals to grow abnormally faster than wild fish.

Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis

The SWOT analysis involves assessing the external factors for perceived opportunities and threats at each stage in the value chain as well as evaluating the internal strengths and weaknesses (Zhang et al., 2007).

Input suppliers

Input suppliers have one key strength: the ability to control the prices at which they trade. Input supplies primarily determine their price using the cost plus approach. Hence, the majority of the input suppliers reported that they have observed an increase in their income within the last 5 years. Another strength identified for input suppliers is the ability to market multiple products and services. Many of the input suppliers have varied knowledge and experience in fish farming. Thus, they are able to provide farmers with training and information, whereas others supply two or more inputs.

The lack of defined contracts between input suppliers and their suppliers, the lack of flexible payment plans, expensive transportation, and pricing constraints are the major weaknesses of the input suppliers. High transportation costs arise from importing from overseas or outside the vicinity of the input supplier, delivery costs, and travel to and from to conduct business.

The major opportunity for input suppliers is the government support in the form of the removal of taxes on aquaculture imports. This provides leverage against the expensive transportation cost associated with imports. The lack of import duty also encourages high private initiatives amongst input suppliers, serving as an avenue for job creation.

The major threat for input suppliers is the fluctuation in the local currency, against the American dollar. The Ghana cedi depreciation against the US dollar affects pricing of goods and services. This results in customers' demand for price reduction which affects income and profit of input suppliers. Another threat some input suppliers face is the delay in shipping and clearing of goods. Input suppliers also face the threat of competition from new entrants.

Producers

The major strength for producers is access to resources such as land. About 85% of the producers own land suitable for aquaculture. This presents enormous opportunities for expanding their production capacities. Another strength identified for the producers is the ability to produce their own fingerlings. Due to some challenges producers face with fingerlings purchased from hatcheries, some producers have started their own hatcheries and many others express desires to do likewise in order to meet their fingerling needs.

The major weakness for producers is that fish farming is capital intensive without many opportunities for loans. Where loans exist, interest rates are so high that the loans are unattractive to farmers. Another major weakness is marketing constraints. Many producers complain that due to high costs of inputs, it is sometimes impossible to sell fish at profitable prices. Only large scale farmers, especially the cage farmers, make reasonable profits because of economies of scale. Marketing was a major weakness also because some farmers often had no idea to whom they wanted to sell their products.

A number of opportunities exist for producers. These include the flexibility of changing existing technology and species to improve production. For pond farmers, polyculture of tilapia and catfish, as well as *Heterotis niloticus*, is increasingly becoming necessary since monoculture of tilapia in the pond environment has proven to be unsatisfactory to some farmers. Another opportunity for producers is the flexibility of changing sources of input such as fingerlings and feed. With over 6 major hatcheries and about 7 different feed brands available on the market, producers have many options in terms of where to get major fish farming inputs.

The major threats producers face are high cost of inputs and feed shortages. Even though inputs are available, farmers find them too expensive to purchase, resulting in their inability to sell their fish at profitable prices. Feed cost is a major challenge, primarily because over 70% of the feed on the market is imported. Another major threat for producers is shortages in the numbers of fingerlings supplied. Counting fingerlings pose significant challenges, thus, hatcheries estimate the numbers based on a previously known number and weight which results in shortages in fingerlings supplied. This greatly affects farmers because feeding and final yield depend on the initial stocking densities. Other threats that producers face include predators, poaching, lack of extension services, and high mortalities of small sized fingerlings.

Processors

Processors' major strength is the ability to operate within a niche market in the value chain. Apart from input suppliers, processors interact with all levels in the value chain, providing regular business and inflow of income. Presently, they also face little or no competition. Processors also benefit from an informal agreed pricing among themselves.

The lack of a formal association is the major weaknesses for processors. When they operate as individuals or informal groups, opportunities for government support and expansion of their business are limited. There are limited avenues for loans and grants for processors if they apply as individuals rather than as formal groups or associations. Processors will also have a unified voice in discussing issues affecting them with authorities if they were to be formal cooperative groups.

The major opportunity for processors is the ability to expand as aquaculture develops. Increasing demand for farmed tilapia will increase demand for processing. This will eventually open up a market for additional processing methods which will benefit current processors if they position themselves strategically in the value chain.

The major threat processors face is the lack of adequate food safety knowledge. The current processing activities are done with little regard for food safety. Processors wear no protective gear such as gloves, nose masks, and hair nets. Sanitation at processing sites is also inadequate. As the aquaculture industry grows and food safety regulations become mandatory, processors face the risk of losing their jobs without adequate food safety training. Processors also face the threat of future competition. Currently, the market is able to absorb the volumes of fish produced, and there is minimal need for other value additions. However, as fish production capacities increase, other processing methods will be needed. Processors will therefore have to place themselves strategically by adopting additional processing techniques. This will help them take advantage of the changes in the aquaculture industry in order to remain competitive.

Traders

The major strength for traders is their ability to control the prices of fish and make profit. Since traders predominantly use cost plus in determining the price of fish, they rarely incur losses.

The major weakness for traders is the fluctuations in their income. The income fluctuations may be attributed to their unstable customer base. This is especially true for retailers because they experience brief market interactions with customers. Since they almost always have no contracts with customers, neither their customers nor their sales are guaranteed.

In terms of opportunities, the majority of the traders believed little opportunities existed for them to succeed in their trade. They reported that they had no knowledge of any government interventions that will encourage their business. The major opportunity identified for traders is the ability to source loans for expansion. However, some traders believed that the loans threatened their businesses because of the high interest rates.

Traders face several threats, the major threat being an increase in crime and robbery on the roads. The disruption of business due to rainfall is also a major threat for retailers. During rainstorms, the traders are often helpless in protecting their wares. Moreover, traders located at poorly planned markets also get cut-off from customers if footpaths leading to them become muddy, thereby reducing their sales. The inability to operate in their own stores or stalls in market centers is also a threat for retailers. These traders face constant risk of evacuation by city task force officials because they sell in unauthorized places such as road sides and pavements.

Food services

Food services have two major strengths, their locations and their products. With regards to location, food services are often strategically placed to take advantage of target customers. Not surprisingly, food service providers rated their location as excellent or very good in their overall performance as a business. In terms of product, the food service providers perceived that they provided customers with well-prepared tilapia which they relished. Thus, in most cases, food service providers reported that their high quality meals promoted their business.

The major weakness of food service providers is their limited investment in advertisement, which apparently is affecting patronage. Other weaknesses identified for food services include unstable customer base and fluctuation in income.

In relation to opportunities, many food service providers perceived that radio and television presented advertising opportunities that they could adopt to promote their businesses. Some large food service providers such as restaurants and hotels currently advertise through billboards and radio but felt that their promotional methods were inadequate. Other opportunities reported include addition of live music bands to encourage patronage, adoption of discounts and other promotional strategies, and extending business hours.

The major threat food service providers face is the risk of evacuation from their current locations. This threat affects primarily the tilapia 'joints' and 'chops bar' operators who may be situated at unauthorized locations. Tilapia 'joints,' which are mostly operated in unsheltered places, are often disrupted by rainstorms. Other threats faced by food service providers include smoke inhalation, high costs of goods, irregular power supply leading to fish spoilage, and customer misbehavior.

SWOT Framework in the form of Factor Evaluation Matrix (FEM)

The factor evaluation matrix (FEM) is commonly used to quantify and summarize qualitative SWOT analysis (Ehlers and Lazenby, 2004). This study used FEM to compare the competitiveness of the different value chain participants in terms of the traditional five marketing factors, i.e., product, place, price, promotion and procurement (process). Product refers to product offered by the value chain participant; place refers to the location of the business in relation to strategy; price refers to the respondents' negotiating power and method of price determination and margins; promotion is whether or not participants perform any promotional and advertising activities; and procurement (process) refers mainly to raw material purchases as it affects production.

Each value chain participant was asked to rate the importance (out of 5, where 1 is not important and 5 is very important) of the five marketing factors to their business. With a separate score, respondents were also asked to evaluated their business and rate their performance (out of 5, where 1 is poor and 5 is excellent) in terms of the five marketing factors. Table 2 presents the average ratings by various value chain actors.

Table 2. *The Factor Evaluation Matrices.*

		Input Suppliers	**Distributors / Wholesalers**	**Marketers / Retailers**	**Restaurants / Food vendors**
Place	Importance - Rating	4.05	3.24	4.54	4.40
	Performance - Rating	3.95	4.00	2.76	4.41
	Weighted Performance	0.20	0.25	0.17	0.23
	Weighted Score	**0.82**	**0.80**	**0.79**	**1.03**
Price	Importance - Rating	4.42	4.40	4.42	4.03
	Performance - Rating	3.58	2.10	2.53	3.84
	Weighted Performance	0.18	0.13	0.16	0.20
	Weighted Score	**0.81**	**0.57**	**0.71**	**0.82**
Product	Importance - Rating	4.68	4.10	4.29	4.22
	Performance - Rating	4.32	4.29	4.25	4.57
	Weighted Performance	0.22	0.27	0.27	0.24
	Weighted Score	**1.04**	**1.09**	**1.15**	**1.02**
Promotion	Importance - Rating	4.26	2.52	2.47	2.66
	Performance - Rating	3.68	3.05	3.10	2.84
	Weighted Performance	0.19	0.19	0.20	0.15
	Weighted Score	**0.81**	**0.48**	**0.48**	**0.40**
Procurement	Importance - Rating	4.63	4.05	3.17	2.17
	Performance - Rating	3.89	2.67	3.19	3.26
	Weighted Performance	0.20	0.17	0.20	0.17
	Weighted Score	**0.93**	**0.67**	**0.64**	**0.37**
	Total Performance Rating	**19.42**	**16.10**	**15.83**	**18.91**
	Total Weighted Score	**4.42**	**3.62**	**3.77**	**3.63**

Input suppliers generally perceived the importance of all five factors very high – rated above 4 – and also evaluated their relative performance quite high. In particular, the average rating for product is 4.32, the highest among the other factors (less that 4 but above 3) suggesting that they value highly the product they offer to fish farmers.

This observation is not surprising because the input suppliers in the farmed tilapia value chain are a highly specialized group with a target market. Apart from the net suppliers who also sell to fishermen, all the input suppliers target fish farmers. Thus, their products are tailored for fish farmers, which ensure that good quality products and services are supplied. Additionally, because the input suppliers, especially feed suppliers and hatcheries, face the threat of competition from new entrants, they may be constrained to provide quality products to remain competitive. Moreover, the increasing need to produce large size fish and in great volumes, especially for cage farmers, has provided a justification for the supply of premium products, particularly feed.

Apart from promotion which received a low rating of 2.52, distributors / wholesalers generally perceived the importance of all the factors as above average or high (3.24 and above). In terms of performance, place and product received high ratings, promotion was rated around average, whereas price and procurements were rated below 3, 2.1 and 2.67, respectively. Since distributors and wholesalers generally are strategically placed, they may depend on their customers (most of whom are retailers) to promote their products by word of mouth, and hence will have little need for other promotional methods. The relatively low rating of price may be because of the presence of many small scale distributors among our sample who compete with a few large scale distributors or wholesalers and are, thus, forced to sell by the market price. The large scale wholesalers usually are subsidiaries of fish farms, hence they have the advantage when they use existing wholesale market price. The low rating of procurement in terms of performance can be attributed to the fact that distributors/wholesalers feel unsafe on roads due to high incidents of robbery.

Restaurants/food vendors generally perceived the importance of all factors high – rated 3.26 and above with the exception of promotion and procurement which were rated 2.66 and 2.17, respectively. They also evaluated the relative performance of the factors quite high, 3.26 and above. Only promotion received a relatively low rating of 2.84, suggesting that even though restaurants/food vendors did not perceive promotion as very important in the success of their business, they still believed that they needed a certain level of promotion to sustain their business. In particular, the use of advertisement media such as radio was perceived as an avenue to promote their business, in addition to introducing sales discounts.

On average, markets/retailers perceived location to be very important and ranked it the highest, 4.54 among the various value chain groups (Table 2). For marketers, location is very important to selling their products and it is not surprising that, to them, place is ranked the highest, followed by price (4.42) and then product (4.29). However, in evaluating their business, product was ranked the highest (4.25), with place and price being rated below 3, at 2.76 and 2.53, respectively. The fact that marketers perceived that they procured good quality products, but ranked their sales locations and product prices below average supports the earlier findings that many marketers perceived their sales locations and prices as threats and weaknesses, respectively. Marketers usually sell in the open market and their wares are frequently at the mercy of the weather. Thus, they are sometimes forced to reduce their prices to enhance sale, hence the recorded low average rankings for place and price.

The average self-evaluated performance ratings for the marketing factors were used to assign a weight ranging from 0 to 1 to each marketing factor (weighted performance in Table 2). The weight was then multiplied by the average importance rating to obtain the weighted score. Higher scores indicate a better performance of the value chain group (Ehlers and Lazenby, 2004). The indices help to evaluate the strengths and weaknesses in marketing mix of the businesses. From Table 2, the weighted scores suggest that product offering appears to be the strength at each stage of the value chain. The weighted score for product is 1.04 for input suppliers; 1.09 for distributors/processors; 1.15 for marketers/retailers; and 1.02 for restaurants/food vendors. Restaurants/food vendors also have a weighted score of 1.03.

A total weighted score well below 3 suggests a weak business with regards to the marketing mix. Scores significantly above 3 indicate a strong marketing position. Thus, from Table 2, input suppliers have a relatively stronger sector within the chain with a total weighted score of 4.42. The other stages in the tilapia value chain also have strong marketing position, given that they each have a score of over 3.0.

Relationships among key actors

The types of relationships among actors in the value chain influence the efficiency of the chain. A common relationship between actors is a business relationship which may be referred to as a linkage. Linkages may be vertical or horizontal. The former occurs between actors along the value chain whereas the latter occurs between actors at the same level of the chain. In the farmed tilapia value chain, both vertical and horizontal linkages are important for efficient movement of products through the chain. However, due to competition, and subsequent lack of information flow among actors at the same level in the chain, vertical linkages are the primary linkages existing in the value chain. Thus, trust building, which is responsible for efficiency in the value chain because of reduced transaction cost, depends solely on vertical linkages. Strong linkages that exhibit trust among key actors are encouraged by factors such ashaving contracts and flexible payment plans between suppliers and customers; preference for dealing with a particular individual among actors at one level of the chain; and efficient flow of information. In this study, because the mode of payment of goods and services in the value chain is mostly cash, many chain actors have short interaction time among themselves. Thus, it appears that the lack of contracts and the inability to obtain products and services on credit constrains the building of trust and stronger relationships among actors.

Apart from input suppliers and producers, and sometimes food services and traders, who show preference for particular actors, many of the chain actors appear not to have strong preferences for dealing with each other. The relationships between actors in the value chain may, therefore, be described as weak relationships, somewhere between spot market (where interactions are shorter) and persistent network (where interactions are continuous) relationships. Figure 5 shows the possible relationships existing among key actors in the farmed tilapia value chain in Ghana. Continuous lines in the figure indicate persistent network relationships whereas broken lines indicate spot market relationships.

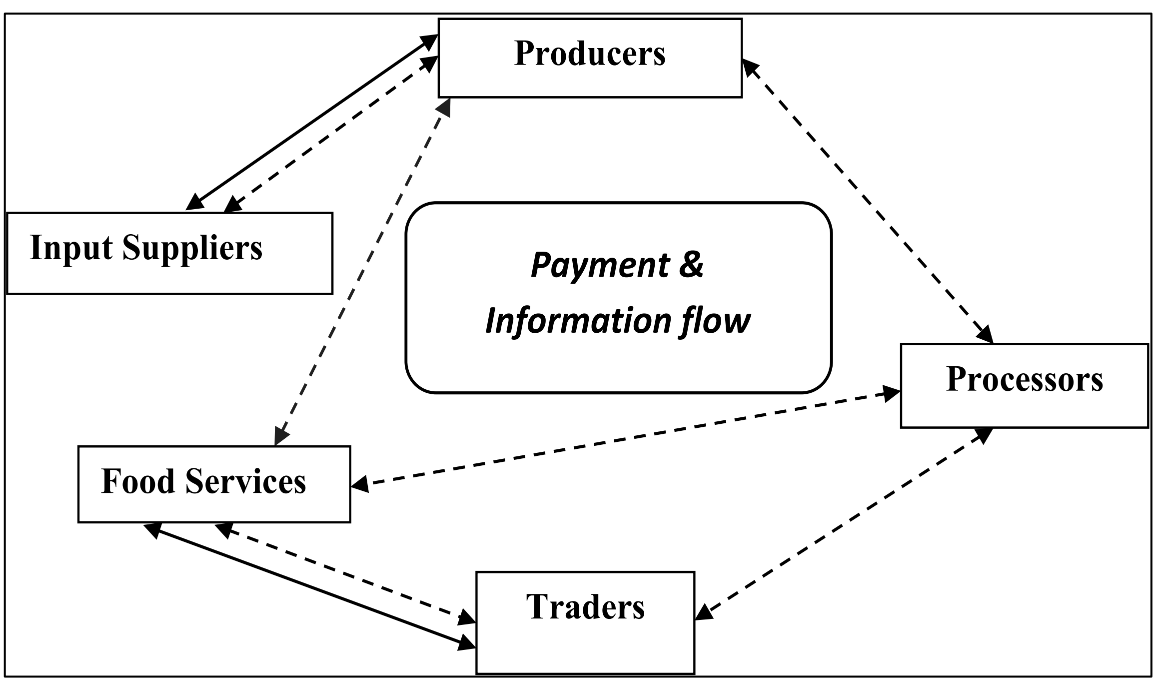

Figure 5. *Relationships among key actors in the tilapia value chain.*

Cost Benefit Analysis (CBA)

A CBA is used to measure all costs and benefits in financial/monetary values (Ghana cedis – GHC) to assess performance in the form of a benefit cost ratio (BCR). Ideally, the present values are used under the assumption that money available now is worth more than money in the future, and the value of the ratio of the present value of benefits to costs greater than one indicates profitability (Campbell & Brown, 2003; Watkins 2010). From Figure 3 however, almost all transactions are conducted as spot market with cash, therefore BCRs are first calculated without discounting the revenues and costs. However, Ghana's economy generally experiences positive inflation and the average inflation reported by the Ghana government in October 2012 was 9.2%. The BCRs for the value chain participants were calculated first without any discounts and then with inflation rate for revenues (Table 3).

Table 3. *Benefit-Cost Ratios for farmed fish value chain participants.*

	Revenue (GHC)	Cost (GHC)	BCR (Unadjusted)	BCR (Adjusted)
Input Suppliers	187,433.83	83,718.70	2.24	2.05
Fish Farmers	31,012.66	44,454.05	0.70	0.64
Distributors / Wholesalers	23,018.86	10,917.80	2.11	1.93
Marketers / Retailers	1,956.79	1,496.96	1.31	1.20
Restaurants / Food vendors	1,022.26	757.16	1.35	1.24

The major cost incurred by input supplies include stocks, transportation, space rental, packaging, electricity, staff emoluments, input costs, and taxes.

The major costs incurred by fish farmers include feed, hired labor and family labor, fingerling stock, electricity, transportation, licensing, rental of space and machinery/farm equipment, harvesting cost, net repair, feed processing, and fingerlings packaging. The major cost incurred by distributors/wholesalers include stock, transportation, packaging, electricity or ice cost, wages, and tax. The major costs incurred by marketers/retailers include stock, electricity or ice cost, transportation, wages, packaging, and space rental, and tax. The major costs incurred by restaurants/food vendors include stock, wages, packaging, transportation, tax, electricity or ice cost, input cost, cleaning, and space rental.

Apart from fish farmers who had a benefit cost ratio of 0.64, all other value chain participants had a ratio higher than 1, with input suppliers having a ratio higher than 2. Thus fish farming appears unprofitable whereas input supplying seems very profitable contrary to what other studies found (Asmah, 2008; MacFadyen et al., 2012). Further investigation was conducted to explain why fish farmers may be making losses compared to the other chain participants. The investigation revealed that the method of price determination used by fish farmers may be the major contributor to their inability to make profit. About 64% of fish farmers priced their products using the prevailing market price, compared to 19% or less for all the other chain participants. Conversely, only about 18% of fish farmers used either cost plus or percentage markup to determine their pricing, compared to 74% and above for the other chain participants. By using the prevailing market price approach, fish farmers face the risk of pricing their fish without taking into consideration the cost of production per fish. This is particularly problematic for small scale farmers, especially pond farmers, who do not have the advantage of economies of scale.

The major reasons why input supply appear to be more profitable relative to the other chain activities include: 1) well defined customer payment transactions, 2) strong customer base, and 3) good record keeping. Input suppliers ensure that they receive prompt payments for the goods and services they provide. In addition to operating on a cash and carry basis, input suppliers are the only chain actors who reported that they receive cash in advance of goods or service provided. This is especially the case for fingerling producers who receive orders and payments months in advance before they deliver. Well-defined payment transactions with customers are also consistent with having contracts, whether formal or informal, with customers. This, in turn, strengthens the relationships between input suppliers and their customers, making them more efficient, and their business more profitable. Compared to the other chain participants, input suppliers also had better records in terms of their revenues and costs which helped them track their profit margins. It appears that chain participants who dealt with fewer items kept better records. This is probably why fish farming appeared to be unprofitable compared with the other chain activities.

CONCLUSIONS AND RECOMMENDATIONS

This study shows that apart from fish farming, all other major chain actors identified (input suppliers, traders, and food services) had a benefit-cost ratio higher than 1.00, suggesting that fish farming is less profitable compared with the other value chain activities. Input suppliers appeared to make the most profit and had the strongest sector within the value chain. To improve the value chain and ensure that the chain is sustainable, we recommend that key actors be encouraged to have well defined payment transactions with customers and adopt flexible payment methods. Chain actors should also form strong persistent linkages among themselves, such as identifying particular actors and dealing consistently with them. These would improve the relationships among actors and ensure efficiency in the value chain. Farmers should also prioritize record keeping of costs and revenues to enable them to track their performance in terms of profit margins.

As far as institutional support is concerned, we recommend that the Fisheries Directorate of Ghana set and enforce standards that will regulate the activities of chain actors, especially hatcheries and processors, to ensure quality products and services are supplied along the chain. Providing safety patrols on major roads that traders use for purchasing and supplying fish will also improve the value chain tremendously. Additionally, food safety training should be provided for key chain actors, especially processors, to ensure the fish products supplied to consumers are safe. Finally, providing access to capital, particularly low interest loans, for all key actors could aid in business expansion.

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TOPIC AREA:
VALUE CHAIN ANALYSIS
❖

VALUE CHAIN ANALYSIS IN SOUTHERN MEXICO

Marketing, Economic Risk Assessment & Trade/Activity/09MER08UA

FINAL INVESTIGATION REPORT

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INTRODUCTION

Tilapia have become one of the most popular food fishes in Mexico. They are frequently used to replace overharvested fish stocks from both freshwater and marine systems. Farm production is occurring in ponds, tanks and in raceway systems, with several domesticated strains. Farmed tilapias are currently sold in several different forms including live, frozen, and fresh on ice. They are also marketed in some value added forms included scaled and gutted, headed and gutted and as fresh and frozen fillets.

We have not been able to find any comprehensive study of the marketing system for tilapia and tilapia products in Mexico. As tilapia become a more important sector of the seafood industry across the country, an in-depth study will be valuable for stakeholders from producers, through harvesters, shippers, processors, wholesale and retail and the eventual consumers.

The value chain has been used as an analytical tool for the aquaculture industry. It will be used to describe the various steps in the pathway from farm to consumer and to determine the competitive advantages that certain stakeholders may have during these steps and processes. It may also identify where additional efficiencies may be gained in the production, processing, transportation and retailing aspects.

OBJECTIVES

The objectives of the activity were:

(1) for the Arizona and Tabasco Principal investigators to participate in the AquaFish CRSP Tanzania workshop to be trained in value chain analysis;

(2) to conduct a value chain analysis of tilapia, (*Oreochromis spp.)* in order to propose improved marketing and management solutions.

(3) to hold a workshop in Tabasco to bring together stakeholders to discuss the value chain model for tilapia in Tabasco and discuss the findings and additional aspects of where improvements in the model may yield the best returns on investment.

METHODS AND MATERIALS

Participation in the AquaFish CRSP Tanzania workshop in order to be trained in value chain analysis

***Objective 1:* for the Arizona and Tabasco Principal investigators to participate in the AquaFish CRSP Tanzania workshop to be trained in value chain analysis**

General Activity Procedure. Participation at the Aquafish CRSP Tanzania workshop of the US PI and HC Co-PI was performed from July 12 to 15 2012. Workshop aimed to train HC Co-PI in value chain analysis in order to develop the project in Tabasco. Subsequently, US PI and HC Co-PI participated in the IIFET 16thBiennial Conference (International Institute of Fisheries Economics & Trade) held in Dar es Salam, Tanzania from July 16 to 20, 2012 in order to get experience and acquire methodology from other researchers.

RESULTS

Objective 1: Participation in the AquaFish CRSP Tanzania workshop in order to be trained in value chain analysis

According to plan, US PI and HC Co-PI traveled to Zanzibar in order to attend the AquaFish Value Chain workshop and to the IIFET 16thBiennial Conference. At AquaFish CRSP workshop, HC Co-PI presented his research objectives and goals in order to get feedback from other researchers. At A&F CRSP workshop, HC Co-PI improved his research scope in order to be more efficient for developing his research Fig. 1.

***Figure 1**. Workshop held in Zanzibar for training on value chain analysis. b. visit to rural farmers at village in Zanzibar (successful story).*

METHODS AND MATERIALS

Value chain analysis of Tilapia

Objective 2: to conduct a value chain analysis of tilapia, (*Oreochromis spp.)* in order to propose improved marketing and management solutions.

The methodology employed in this study was based on PCARRD-DOST (2011) and Jamandre *et al* (2012) with modification according to actual regional conditions.

Study areas and Data collection

The study was identified where there is more aquaculture activity. According to Gama Campillo *et al* (2012) these areas were the Centro and Cunduacan municipalities in Tabasco. In the case of Campeche, the municipality of Atasta was selected due to the development of the industry. Farmers were targeted based on openness to survey participation and farm size, with medium size farmers being the primary targets.

Questionnaires were designed and a survey conducted with the stakeholders in the Tabasco tilapia value chain:

- Tilapia farmers
- Custom harvesters – transporters
- Wholesalers and Retailers
- Consumers

The survey – questionnaires were completed in two parts. In one portion was a field survey conducted by faculty and/or students to reach stakeholders. The second portion was done to reconfirm data during a workshop from stakeholders also to discuss issues and concerns and to establish new links.

Data were gathered from targeted actors (medium farmers)- definition of size of actors, available in table 1. Selection of actors was based on actors' disposition of participation.

Table 1. *Definition of size of actors based on working productive land*

Definition of actor	Working land
Small size farmers	>500 m^2
Medium size farmers	500-1500 m^2
Large size farmers	>1500 m^2

Laboratory/nursery operators were targeted according to previous answers of producers in order to track the value chain targeted. The same methodology was used for targeting aqua-agri shops and traders/retailers.

The value chain analysis consisted of the following: Firstly, at its most basic level, a value-chain analysis *systematically maps the economic agents* participating in the production, distribution, marketing, and sales of a particular product (or products). This mapping assesses the characteristics of economic agents, profit and cost structures, flows of goods throughout the chain, employment characteristics, and the destination and volumes of domestic and foreign sales. Such details can be gathered from a combination of primary survey work, focus groups, informal interviews, and secondary data.

Second, value-chain analysis plays a key role in *identifying the distribution of benefits of economic agents in the chain*. That is, through the analysis of margins and profits within the chain, one can determine who benefits from participation in the chain and which economic agents could benefit from increased support or organization. This is particularly important in the context of developing countries (and agriculture in particular), given concerns that the poor in particular are vulnerable to the process of globalization. One can supplement this analysis by determining the nature of participation within the chain to understand the characteristics of its participants.

Third, value-chain analyses are used to *examine the role of upgrading within the chain*. Upgrading can involve improvements in quality and product design that enable producers to gain higher-value or through diversification in the product lines served. An analysis of the upgrading process includes an assessment of the profitability of actors within the chain as well as information on constraints that are currently present. Governance issues play a key role in defining how such upgrading occurs. In addition, the structure of regulations, entry barriers, trade restrictions, and standards can further shape and influence the environment in which upgrading can take place.

Finally, value-chain analyses *highlight the role of governance* in the value-chain. Governance in a value-chain refers to the structure of relationships and coordination mechanisms that exist between economic agents in the value-chain. Governance is important from a policy perspective by identifying the institutional arrangements that may need to be targeted to improve capabilities in the value-chain, remedy distributional distortions, and increase value-added in the sector.

At the heart of the analysis is the mapping of sectors and key linkages. The value-added of the value-chain approach, however, comes from assessing these intra- and inter-actor linkages through the lens of issues of governance, upgrading, and distributional considerations. By systematically understanding these linkages within a network, one can better prescribe policy recommendations and, moreover, further understand their reverberations throughout the chain.

The methodology addressed the following issues, and began with understanding the nature of final markets, the industry, which are increasingly the driver in many value chains:

- The point of entry for value chain analysis
- Mapping value chains
- Product segments and Critical Success Factors in final markets
- How producers access final markets
- Benchmarking production efficiency
- Governance of value chains
- Upgrading in value chains
- Distributional issues

Data processing and analysis

Data processing was performed according to Jamandre *et al* (2012) the methods of analysis were as follows: Flowchart analysis from downstream to upstream; Descriptive statistics and relevant performance metrics (qualitative)

RESULTS

Objective 2: to conduct a value chain analysis of tilapia, (*Oreochromis spp.)* in order to propose improved marketing and management solutions.

Tilapia industry in Mexico is one of the most active and technological activities; this industry contributes 7.6% of the total aquaculture products in the fisheries national production. The Tilapia industry in Southeast Mexico has grown by a considerable increment in the last 10 years, almost all Tilapia production is sold within the region.

The supply chain in the region is relatively simple. It is based on inputs from providers of fingerlings, suppliers to grow-out producers, then to traders and retailers. Tilapia products are not subject to any fillet processing and in some cases the product is even sold fresh/live, not even gutted or headed. A small amount of the product is taken out of the region by traders, this condition occurred with the producers outside of cities or hot zone marketing areas, where they have sold their product to traders.

Key customers and product form

We identified two value chains in the region, first based on production and marketing in the region and the second one production and processing is developed outside the region and just marketing is performed in this area. Key customers are classified in the two chains as; traders/retailers and end users for the first chain and institutional buyers (supermarkets) and fresh markets (mainly Mercado Pino Suarez in Villahermosa).

Product form for household customers are basically two; medium size Tilapia (350 – 500g) and large size Tilapia (>500), generally bought at the farm site or from retailers, it is the same size sold in supermarkets and fresh markets. As there is no processing in the region, large Tilapia is sold to end consumers. Small size Tilapia is regularly consumed by farmers or in some scarce occasions sold to traders, also we have seen in some small size restaurants that it is available. Small size Tilapia (<350g) are sold by kilogram (from 3 to 4 pieces per kg). Customers are indifferent to the color of skin Tilapia in the region as the principal Tilapia product is grey Tilapia. The common food recipes for Tilapia are charcoal grilled and fried. Most of these customers buy Tilapia direct at the farm, at fresh small markets and at mobile vendors.

There are other Tilapia products (frozen fillets, fish fingers, nuggets) these are mainly sold in supermarkets and come from outside the region (produced and processed), it was impossible to trace those products as there are no reliable information. Also all those institutional buyers were not in the focus of this study.

Major players and their activities

The major players and their activities are illustrated in Fig. 2. Agri/aqua supply stores offer products indispensable for aquaculture activities such as: feed (in different stages and brands) equipment (aerators; many forms and brands) materials (nets, liners, plastic bags) oxygen (for fish/fingerlings transportation).

Laboratory/ nursery operators provide sex-reversed fingerlings in two forms; for ponds/tanks production fry that could come in two ages; 30-35 days old (that required nursery in cages in the same pond or tank) with an average price of 85 centavos and fingerlings of 45-60 days old that are more expensive with an average price of 1.20 pesos. And for cage production, the requirement of fingerlings is 45-60 days old. The Tilapia strain sold in these laboratory-nursery facilities are; Chitralada+ Gift, Tabasco line (breeding selected) and Chitralada. Some of these operators develop improved brood stocks and they presume of high sex reversed ratios (>97%) but unfortunately in some cases is not true.

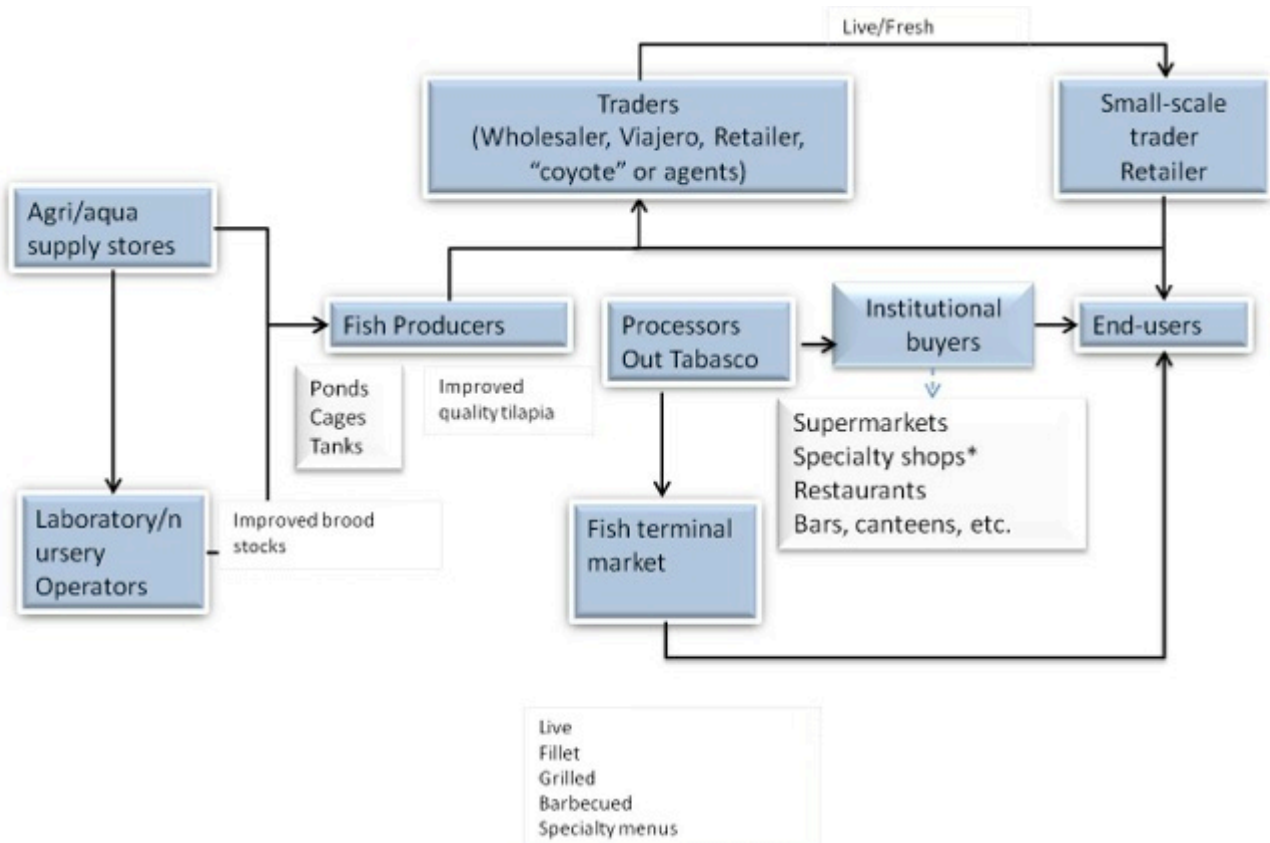

Figure 2. *Major players on Tilapia industry in Southeast Mexico*

Fish producers are in two kinds; tanks and ponds users. The tanks producers work in plastic lined tanks (from 6 to 9m diameter tanks) with aeration and rely on feed as main source of protein. Pond users work in earthen ponds (from 200 – 500 m^2 ponds) in some cases they used aeration and unconsciously they use primary production as complement of protein source. All of the producers practice the size selection at mid-cycle in order to reach better and uniform sizes. Usually a normal cycle will take from 5 to 7 months to reach commercially desired sizes.

Traders are in two forms; traders/retailers that buy directly from producers and sell direct to end consumers with mobile shops that circulate in small towns and even residential areas outside Villahermosa. And traders who buy direct from producers and sell to small fresh markets and small retailers out of the region (Coatzacoalcos, Veracruz State).

For the outside of the region value chain, processors/retailers sold Tilapia (undefined source of Tilapia) to the State fresh Market (Mercado Pino Suarez) and they sold to end consumers. Institutional buyers like supermarkets buy from outside of the region processors and producers, many time they are part of a bigger chain that import their products (mainly China, Vietnam and Thailand).

Major routes of products

Fig. 3 shows the Tilapia supply chain's major route in Southeast Mexico. For this chain the major transshipment point is in Villahermosa at the Mercado Pino Suarez. Although this transshipment point plays only a role in the second outside of Tabasco supply chain, we could not distinguish a transshipment point for the other regional chain as most of the Tilapia is sold either at mobile vendors, at farm site or small local fresh markets.

The aqua/agri shops, laboratory/nursery operators and grow-out farms are located in Cunduacan, Cardenas and Centro municipalities of Tabasco and Atasta in Campeche State. The major demand centers are Cunduacan, Villahermosa Cardenas, Tabasco and Coatzacoalcos, Veracruz, Ciudad del Carmen and Reforma, Chiapas.

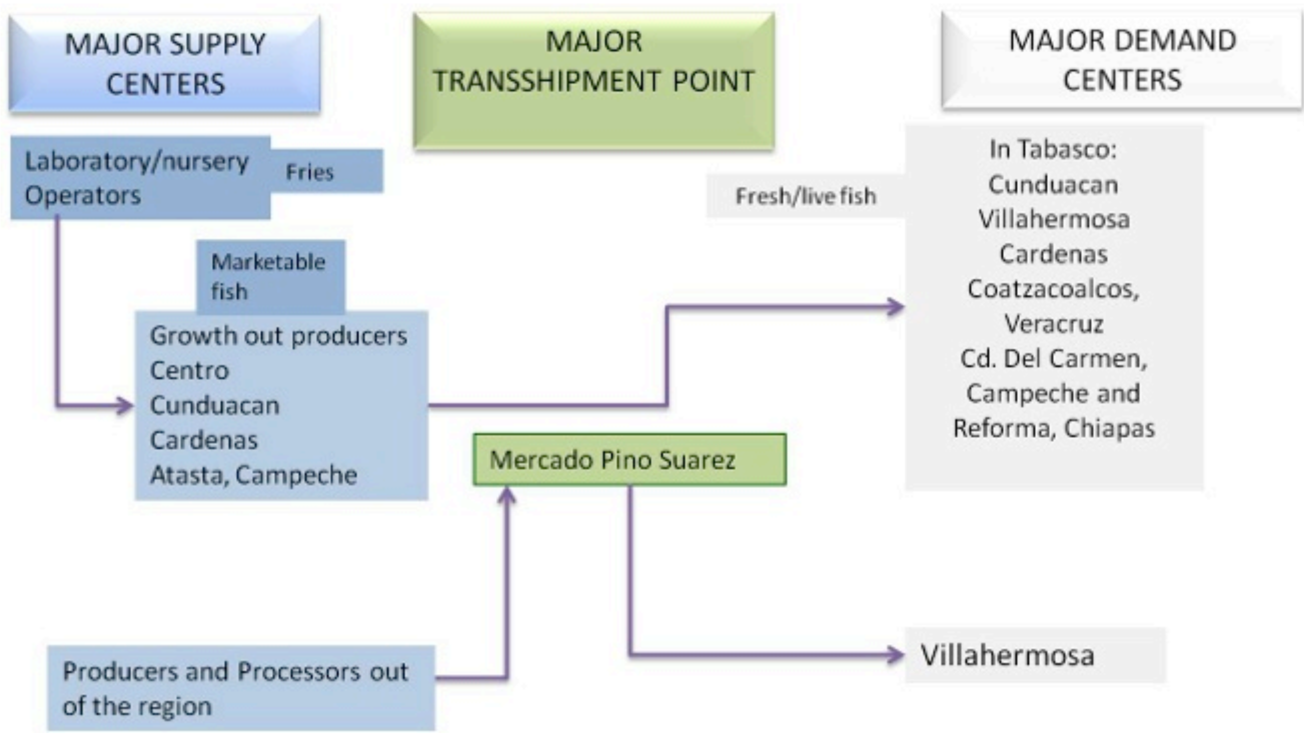

Figure 3. *Major routes identified in the value chain*

Fig. 4 describes the route of products. In the first regional supply chain laboratory/nursery operators in Centro and Cunduacan, Tabasco and Plan de Ayala, Campeche provide sex reversed fingerlings to the farms (tanks and ponds) in Centro, Cunduacan, Cardenas in Tabasco and Atasta in Campeche. Producers after 5 to 7 months provide mainly two Tilapia (live/fresh) sizes to traders that are then sold in Villahermosa, Cunduacan, Cardenas, Tabasco, Reforma, Chiapas and Ciudad del Carmen in Campeche. Also some of these traders sold frozen Tilapia to retailers in Coatzacoalcos, Veracruz. And finally Tilapia producers sold live/fresh Tilapia to end consumers at farm site.

For out of region supply chain, grow-out/ processors sold Tilapia to traders that sold frozen Tilapia to retailers at Mercado Pino Suarez in Villahermosa, Tabasco. Institutional buyers buy from processors out of the region (unidentified supply chain).

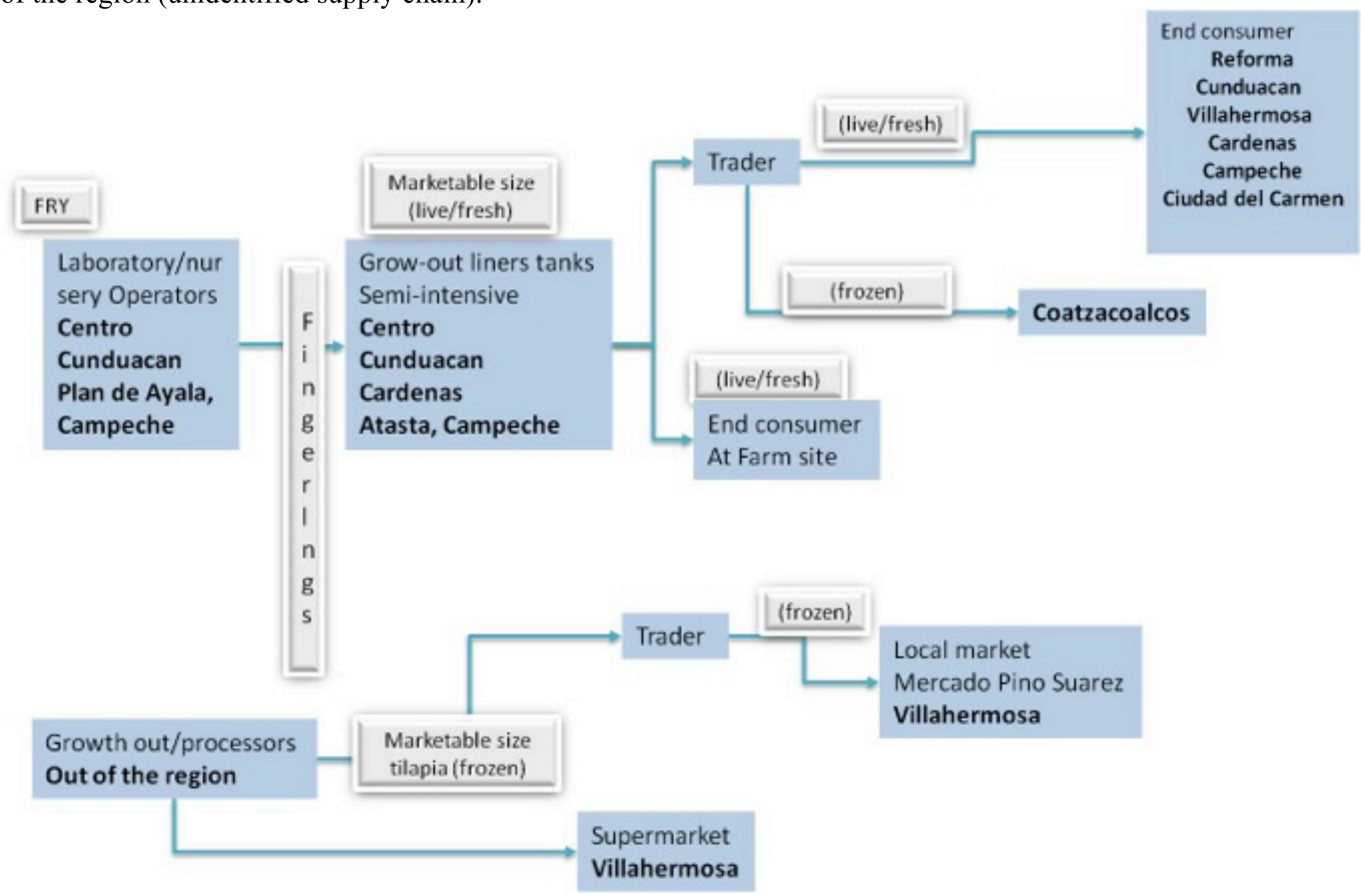

Figure 4. *Product flow in the Tilapia value chain*

Payment flow

In general payments are made on spot cash or cash on delivery (COD) depending on different situations between laboratory/nursery producers, grow-out producers, traders/retailers and end consumers, in some occasions it is known that some producers give credit to large traders (this information could not be identified). For the out of the region supply chain, the payment flow could not be identified although some producers argued that institutional buyers required credit for long periods (usually institutional buyers pay in 1 to 3 months) Fig. 5.

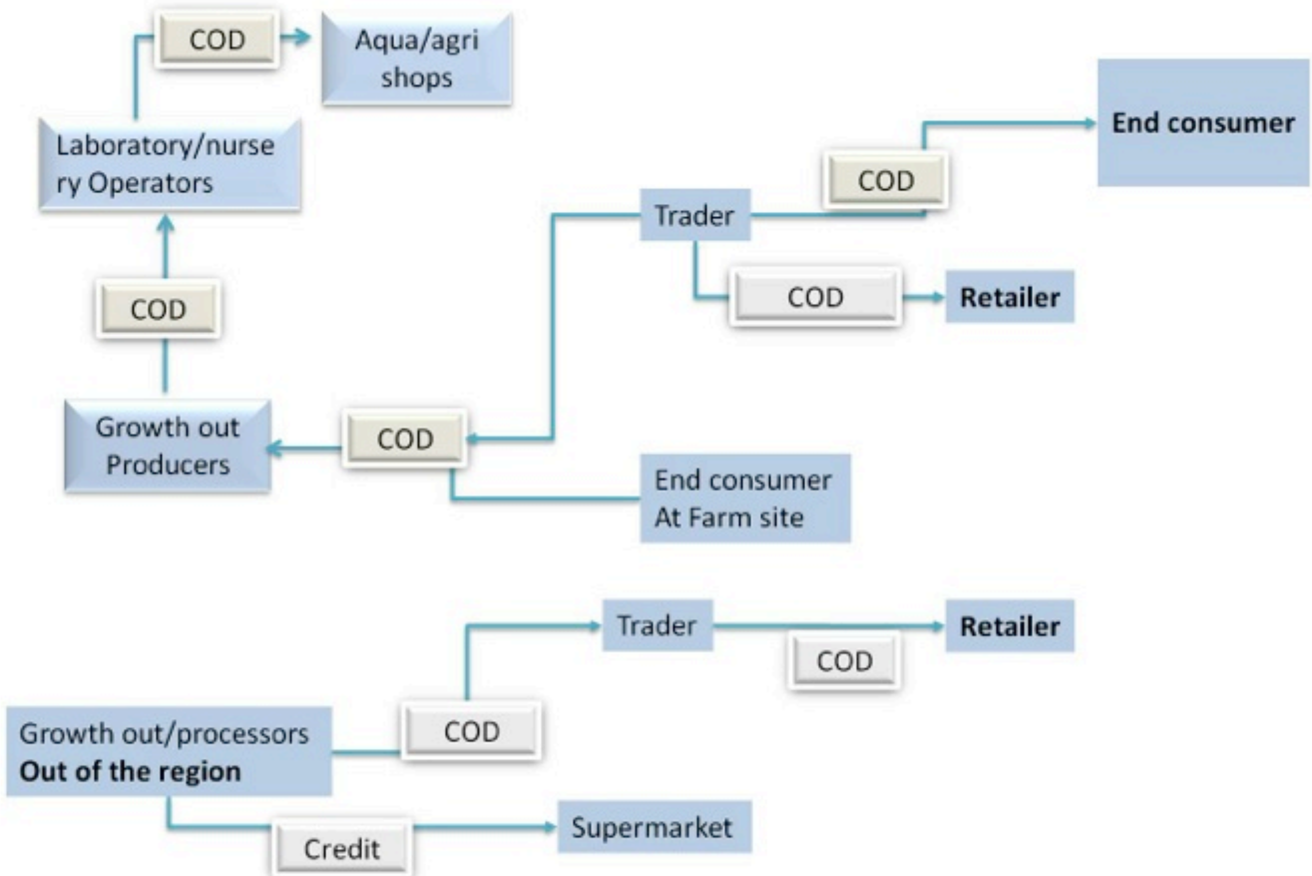

Figure 5. *Payment flow in the Tilapia value chain*

External influence/ concerns

1. Program support from the government in some cases results in sub-optimal product quality. There is no direct influence from technology development arising to production areas through government programs. There is a gap between university/institutions, technology developers and government extension programs.

2. Certification with providers. Commercially available sex reversed fry are not quality tested as advertised from providers. Equipment and material are very often high priced and not high quality. Feed inputs are high priced due to manufacturers being far away from the region. There is also a big concern with the electricity fare, as there is no special electricity fare to farmers.

3. Excess of bureaucracy. Most of the permits, certifications or regulations are too many and too energy/ time demanding that in some cases become impossible for many of the actors in the supply chain.

4. Lack of training/ technical assistance. There are a critical number of active Tilapia farms. Only the 35% of the total official Farms in the State of Tabasco are active or working. Lack of training and technical assistance is the most frequent cause for this issue together with natural disaster.

Recommendations

The following are some recommendations to address the various concerns of chain players;

1. Encourage the establishment of high quality reliable hatchery-nursery facilities that can provide different sizes or establish separate hatcheries and nurseries in order to offer bigger size fingerlings and thus shorten grow-out cycle.

2. Conduct market promotion activities highlighting the various niche opportunities of tilapia among growers and consumers (added value, market small sizes in new niches, specialty shops).

3. Motivate the participation of small farmers in supply chains by setting up an incentive scheme through a mix of patronage refund and profit sharing.

4. Provide capital windows to improve facilities and reduce logistics and transaction costs in the entire supply chain of Tilapia.

METHODS AND MATERIALS

Workshop with major players from the supply chain

Objective 3. Hold a workshop in Tabasco to bring together stakeholders to discuss the value chain model for tilapia in Tabasco and discuss the findings and additional aspects of where improvements in the model may yield the best returns on investment

We organized a workshop with major players of our traced supply chain. We were also assisted by interested students, professors and technicians. The workshop was held at the Laboratorio de Acuicultura Tropical. We had the participation of Dr. Wilfred Jamandre to assist in the workshop. The program of the workshop was: presentation of advantages of supply chain, basics, experience in Philippines and a round table with participants.

RESULTS

Objective 3. Hold a workshop in Tabasco to bring together stakeholders to discuss the value chain model for tilapia in Tabasco and discuss the findings and additional aspects of where improvements in the model may yield the best returns on investment

We organized a workshop after the interviews in order to reaffirm data gathered and discuss concerns and issues in an open way. The workshop was held at the Laboratorio de Acuicultura Tropical from Division Academica de Ciencias Biologicas, Universidad Juarez Autonoma de Tabasco. We had 23 participants (table 2) including producers, fingerling suppliers, feed suppliers, traders, students, professors and technicians.

The most important highlights of the workshop were the open participation of players, where they confirmed the data gathered before. They presented their concerns and issues that were pretty similar to all players in the supply chain. Among impacts of the workshop there was the beginning of new collaboration among actors where they decided to acquire the new system presented at Dr. Jamandre's talk.

The workshop held at UJAT was an eye opener of supply chain players, where they for first time could understand that there should not be a confrontation between actors, but rather there should be a efficient, dynamic supply chain where all can make profits.

Figure 6. *Workshop held at UJAT.*

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TOPIC AREA:
VALUE CHAIN ANALYSIS

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VALUE CHAIN ANALYSIS OF FRESHWATER SMALL-SIZED FISH IN CAMBODIA

Marketing, Economic Risk Assessment & Trade/Activity/09MER09UC

FINAL INVESTIGATION REPORT

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INTRODUCTION

Background

Cambodia is one of many countries in Southeast Asia rich with natural resources, and in particular, fisheries resources, which include inland capture fisheries, marine capture fisheries and aquaculture (both inland and marine). In 2009, total fish production was 515,000 tons, in which inland capture fisheries shares 390,000 tons representing nearly 76% of the total fish production, followed by marine capture fisheries 75,000 tons (14.5%) and aquaculture 50,000 tons (9.7%) (FiA, 2010). Inland capture fisheries were ranked fourth in the world after China, India, and Bangladesh in 1996 (FAO, 1999). Freshwater fisheries (inland capture fisheries), contributing around 90% of the total inland fisheries, are considered to be the most productive inland fisheries in the world and contribute around 60% of the country's commercial fisheries production (Ahmed et al., 1998).

Fish is the most productive fisheries resource and is believed to play a crucial role in ensuring food security to millions of people in the whole country. Most protein that Cambodian people receive comes from fish, which makes up about 75% of animal protein intake. Beyond meeting people's basic needs, fish also provides both direct and indirect benefits via employment and income generation to people and contributes to national economic growth through GDP (about 12%).

Freshwater small-sized fish are a good source of protein. Because they are not preferred to larger fish species and therefore have low market value, small-sized fish is considered an important foodstuff for the poor. Annually, thousands of tons of small-sized fish are caught in the Cambodia Mekong basin. It is estimated that at least 16,000 tons of small-sized fish were caught by using only one commercial type of fishing gear – bag net or dai – in the season of 2004 – 2005 (Hortle et al., 2004). Moreover, in the 2006 – 2007 season, the total catches of all dai was around 18,000 tons, while the average catch of each dai was about 300 tons, with ranged from 59 tons to 603 tons. More than 95% of the total dai fish catch was small-sized fish, of which the dominant species was Henicorhynchus spp. (52%) (FiA, 2007; and So et al., 2007).

According to Loc et al. (2009), 29,064 tons of *Henicorhynchus/Labiobabus spp.* (grouped as *Trey Riel* in Khmer) was traded in Cambodia, representing 55% of the Dai fisheries. Due to this abundance, especially in the short period during peak fishing season (December to January) along the Tonle Sap and Mekong River, these fish are typically landed in small spots and in a poor state of preservation or severely damaged from the capture method (So et al., 2005).

The Fisheries Administration before 1975 determined three grades of fish from riverine areas – lacustrine and marine catches. The last, 3rd grade of this determination referred to small-sized fish which was defined as all small species of fish with a cheap price compared to the 1st and the 2nd grades. Normally, it was used for processing into fish paste, low-quality fermented fish and smoked fish, and sun dried fish for animal feed. This category has been considered as trash fish when in abundance (FiA, 2002).

There is increasing demand and trade in the Lower Mekong Basin (LMB) of Cambodia for small-sized fish for human consumption (fresh and processed), and fish and animal feed. Significantly, pond and cage culture and crocodile farming in Cambodia are dependent on freshwater small-sized fish used for feed. Therefore, there is also conflict between the use of small-sized fish for feed and for human consumption. In some cases, such feed consists of fish species traditionally used as cheap food for people. This allocation of fish resources to aquaculture and animal feed may result in negative impacts on food security, employment and income generation. According to So et al. (2005), small-sized fish represent from 60 to 100 percent of the total feed used for fish culture and animal raising depending upon feeding strategies adopted by various farmers (So et al., 2005). It is the economics of the different uses of small-sized fish in different localities that direct the fish one way or the other. There are also trade-offs between direct food benefit and the indirect employment and income generation opportunities afforded by feeding for aquaculture. It has been argued that it would be more efficient and ethical to divert more of the limited supply to human food, using value-added products. Proponents of this suggest that using small-sized fish as food for domestic consumers is more appropriate than supplying fish meal plants for an export, income oriented aquaculture industry, producing high-value commodities. On the other hand, food security can also be increased by improving the income-generation abilities of poor people, and it can be argued that the large volume of people employed in both fishing and aquaculture has a beneficial effect. This raises some important questions regarding the social, economic and ecological costs and benefits of aquaculture, its sustainability and future trends.

To date, there has been no comprehensive study of the marketing system for small-sized fish in the LMB. The small-sized fish industry for food and feed in the LMB of Cambodia has spontaneously developed without any comprehensive analysis of the markets for the products, particularly the lack of information on the stakeholders and marketing practices. Therefore, there is a need to conduct a study covering all of the aspects of value chain for small-sized fish in the LMB. The results of this study will be useful for development of policy recommendation for upgrading current harvesting and management of freshwater small-sized fish species in the LMB in order for sustainable utilization of this limited resources. Moreover, this study will be vital for further development of the small-sized fish industry in order to stabilize and sustain the contribution of the small-sized fish to food security, job creation and marketing in the LMB.

Objectives

The overall objective of the study was to conduct a value chain analysis of freshwater small-sized fish in the Lower Mekong Basin of Cambodia in order to propose improved marketing and management solutions. The specific objectives were:

to describe and analyze situations of stakeholders participating in the value chain of freshwater small-sized fish;
to analyze value chains of freshwater small-sized fish; and
to propose improvements for upgrading the value chain, for improved marketing and management solutions.

METHODS

Scope of the Study

The duration of the study was 7 months, from June 2012 to December 2012. This included questionnaire design and pre-test, study areas and sample selection, data base design, data entry, data analysis, and report writing. This study was conducted in four provinces, namely Kandal, Kampong Chhnang, Battambang and Siem Reap provinces, and in Phnom Penh city. Phnom Penh and Kandal province are in the Mekong-Bassac Rivers area, and Kampong Chhnang, Battambang and Siem Reap provinces are near and around the Great Lake-Tonle Sap area (Appendix A, Figure 2.1). In total, there were 10 districts, 19 communes, and 38 villages selected for data collection.

Sample Selection

Stakeholders relevant to the value chain of freshwater small-sized fish were categorized into 6 different groups: fishermen, fish farmers, traders, exporters, processors and end consumers based on their different roles and functions in the chain. In this study, fisherman referred to people who engaged in all scales of fishing activities such as small scale, medium scale and large scale, (bag net/Dai) who caught freshwater small-sized fish either year round or seasonally for household consumption and sale. Fish farmers referred to people who cultured fish such as Snakehead, Pangasius catfish, etc., by using freshwater small-sized fish as fish feed. Traders focused on collectors/middlemen, wholesalers and retailers of either fresh or processed freshwater small-sized fish in markets. Exporters meant chain actors who exported either fresh or processed freshwater small-sized fish to other countries. Processors referred to chain actors who bought fresh freshwater small-sized fish for processing into final or finished preserved products. Lastly, end consumers referred to the ones who bought freshwater small-sized fish either in fresh or processed forms for household consumption or final use.

These groups were purposively chosen from each study area. In total, 206 individuals were structurally interviewed in the four selected provinces and in Phnom Penh city, which included 50 fishermen, 40 fish farmers, 50 traders, 5 exporters, 11 processors, and 50 end consumers (Appendix B, Table 2.1). Moreover, key informants (KIP) such as officers of municipal and provincial fisheries administration cantonment and local authorities in Phnom Penh and in the four provinces were also interviewed, but they were not included in the number of samples selected in this study.

Data Collection

Both primary and secondary data were used in this study. Primary data was obtained from various types of selected interviews through the research. The sampled households were interviewed by using different designed questionnaires for fishermen, fish farmers, traders, exporters, processors, and end consumers, with the emphasis on value chain of freshwater small-sized fish. Moreover, semi-structured interviews were also done with provincial fisheries administration cantonment officers, local fisheries officers and local authorities to get broader understanding on status of freshwater small-sized fish with regard to fishing status, trade, processing and consumption in locality, and to clarify and compliment information obtained from individual interview with the stakeholders.

Secondary data was obtained from government, NGOs and other sources to get general and in-depth knowledge and understanding on concerning issues.

Data Analysis

The primary data – both qualitative and quantitative - was stored in the Access software program. Quantitative data was analyzed, including descriptive statistics, frequency, percentage, mean, and cross-tabulation. The descriptive statistical analysis was used to describe the characteristics of the target stakeholders. Frequency, percentage, and mean were used in the comparative analysis to compare the mean value between the groups. Cross-tabulation was made to describe and compare the data within and between the group stakeholders. Moreover, for qualitative data analysis, data was analyzed and synthesized by two methods: 1) the data was grouped by question and then coded in order to convert into numeric, and analyzed by using descriptive statistics to explain and describe business activities; and 2) The data was synthesized by question, and described those information based on household respondents' perceptions. The qualitative data was used to provide deep understanding on root issues of each chain actor.

RESULTS AND DISCUSSION

This chapter presents the result of the study of the value chain analysis of freshwater small sized fish in the Lower Mekong Basin (LMB) of Cambodia. It consists of four parts. The first part presents the general situation and livelihood activities of chain actors in the value chain while the second part describes the value chain analysis and marketing channel of freshwater small-sized fish. The third part shows the perception and challenges/constraints of chain actors, and the fourth part provides major suggestions for upgrading the value chain of freshwater small-sized fish in Cambodia, including requests of chain-actor respondents as well.

General Situation And Livelihood Activities Of Chain Actors In The Value Chain

Fishermen

Socio-demographic Characteristics of Fishermen

The total samples of fisherman households were 50. Of this, 13 (26%) were female respondents. The average age was 43 years, ranging from 23 to 65 years. Overall, the majority age group of fishermen was 31 to 50 years with 54%. Age of female fishers was 40 years, ranging from 24 to 57 years while male was 44 years on average, ranging from 23 to 65 years (Appendix B, Table 3.1).

The average fishing experience of sample fisher households was about 24 years, ranging from 2 to 50 years. An average experience for male fishers was 25 years, higher than females who had only 19 years (Appendix B, Table 3.2).

Fishing Activities

The fishing calendar of inland capture fisheries in Cambodia is divided into two seasons: open season (from October to May) and closed season (from June to September). Open season consists of peak period and low period of fish caught, especially small-sized fish caught. The study revealed that nearly 70% of fisher households fished year round, meaning that they fished in both open and closed seasons because all of them were subsistence. However, only 30% fished in open season, while 2% fished occasionally (when they were free) (Appendix B, Table 3.3).

Normally, peak and low periods of fish caught was the same for all fish regardless of species and size. The peak period started from November until February, and low period started in October, March, April, and May (Appendix B, Table 3.4). However, these months might be found varied across the provinces. According to Leng (2006) there are two peak migration periods of fish, particularly *Henicorhynchus spp.* (i.e. Trey Riel in Khmer), from the Great Lake flood plains, via Tonle Sap River, to the Mekong River. One of the peak migration periods is at the end of December and the other is at the end of January each year. Each period lasts for 6 to 10 days before the full moon.

There were many different types of fishing grounds where fisher households normally went fishing in the study areas such as: Great Lake, Tonle Sap River, Mekong River, Bassac River, small lakes/rivers, inundated forest and canals. Majority of fisher households went fishing in Tonle Sap River in both open and closed seasons (49.5%), followed by the Great Lake (22.3%), inundated forest (11.7%), and small lakes/rivers, Mekong River, canals and Bassac river (16.5%), respectively (Appendix B, Table 3.5).

The purpose of fishing was for household consumption, processing and sale (both fresh and processed forms). 70% of fisher households went fishing for both household consumption and sale, while 28.6% for processing and only 1.4% for household consumption only. Around 90% of fish caught was for sale and about 10% was kept for household consumption.

Fish Catch: Species, Volume and Price of Freshwater Small-Sized Fish

On average, fisher households went fishing 3.3 months in peak period and 4.5 months in low period of open season, and 3.9 months in closed season. During peak period, they spent more days for fishing activities with 22.2 days per month and slightly different for that during low period which was 20.9 days per month. However, during closed season they went fishing only 18.3 days per month. Regarding volume of fish caught, it was different by period and season. The average volume of fish caught for all fish species in peak period was 656.1 kg per day per household, ranging from 8 to 15,000 kg, of which 77.5% (508.5 kg) was small-sized fish. However, in low period they could catch only 190.2 kg per day per household, ranging from 3 to 7,500 kg, of which 53.6% (102 kg) was small-sized fish. Fish was scarce in closed season, so that only 6.4 kg per day per household could be caught, ranging from 0.6 to 20 kg, of which 68.7% (4.4 kg) was small-sized fish. In open season, especially in peak period fisher households were heavily dependent on fishing activities for their daily living. They could earn, on average, USD 164.4[π] per day per household by selling their fish, in which small-sized fish shared 66.6% (USD 109.5) of that income. In the low period, they could get only USD 38.8 per day per household from fishing activities, of which 43.2% (USD 16.8) was from selling small-sized fish. However, in closed season they could earn less income from fishing activities since not much fish could be caught and the fish was mostly kept for household consumption while the surplus for selling is rare. Therefore, each household could earn only USD 5.9 per day from selling fish, of which 61% (USD 3.6) was from small-sized fish. Besides this source of income, fisher households derived more income from some livelihood activities including hunting rat, culturing fish, selling wood (for making fishing gears and cage), rice and gas, planting vegetables and lotus tree, and laboring. These activities were mostly done in closed season when they were not very busy with fishing. On average, they could get only USD 9.9 per day in peak period, USD 10.4 per day in low period, and USD 8.1 per day in closed season. Compared with income from fishing activities, it was far less (Appendix B, Table 3.6).

Approximately 49 species of small-sized fish (including juvenile of big-sized fish species) were caught by fisher household in the study areas (Appendix B, Table 3.7). Around 24,753 kg of small-sized fish were caught per household in the last open season (2011-2012) in which 23,233 kg were caught in peak period and 2,124 kg were caught in low period. Furthermore, in the last closed season (2011-2012) 300 kg of

[π] Exchange rate: USD 1 = 4,000 Riel

small-sized fish were caught. Totally, at least 24,918 kg of small-sized fish were caught per household last year (both open and closed season) (2011-2012) (Appendix B, Table 3.8).

In terms of frequency of catch, the top ten species of freshwater small-sized fish were identified. The most commonly caught species were: *Henicorhynchus spp.* (Riel), *Puntioplites spp.* (Chrokeng), *Mystus spp.* (Kanhchos), *Osteochilus spp.* (Kros), *Yasuhikotakia spp.* (Kanhchrouk), *Cyclocheilichthys spp.*[*] (Chhkok), *Dangila spp.* (Khnorng Veng), *Pangasius spp.* (Chveat), *Morulius spp.*[*] (Kaek), and *Trichogasterv spp.* (Kompleanh), respectively (Appendix B, Table 3.9). Moreover, in terms of volume of fish caught, the top ten fish species were determined: *Acanthopsoides spp.*[*] (Reus Chek[*], *Henicorhynchus spp.* (Riel), *Paralaubuca spp.* (Sleuk Reussy), *Dangila spp.* (Khnorng Veng), *Cirrhinus Microlepis* (Kralang[*]), *Labiobarbus spp.* (Arch Kok), *Rasbora spp.* (Changva Moul), *Clupeichthys spp.* (Bandoul Ampov), *Yasuhikotakia spp.* (Kanhchrouk), and *Pteropangasius Pleurotaenia* (Chhveat) respectively. Price of small-sized fish was varied by species and seasonality of fishing but ranged from USD 0.1 to 1.5 per kg. In terms of price, the top 10 fish species were identified: Andat Chhke[*], Phtoung, Reus Chek[*], Kromorm[*], Pra Kae[*], Kompleav, Kaork, Kompream, Pou[*] and Chhlaing[*] (Appendix B, Table 3.10). Small-sized fish were most of the time sold in mixture form. In some cases, when it was scarce or had more commercial value compared to other species, it was sold separately.

Trend of Fish Catch: Volume and Price

Volume of fish catch per fishing effort in the last season of 2011-2012 increased by 60% to 68% of fisher households, compared to that before 2011 (Appendix B, Table 3.11). This resulted from the recent fisheries reform which cancelled all fishing lots, making fish more accessible to fisher households, especially small-scale fishers, and increasing numbers of fish shelters since some of the ex-fishing lots were taken as fish conservation areas. Besides this, flooded forest areas, and other natural areas were more protected and conserved. Moreover, reinforcement of fisheries law by putting more effort on patrolling and suppressing overfishing and illegal fishing also contributed to make fisheries resources more abundant. As reported by fisher households in 2011-2012 the water level was deeper than the previous year, which brought many fish from different water sources and made the migration of fish easier.

The majority of fisher households (60% to 70%) reported that the price of fish in the last seasons of 2011-2012 had decreased compared to that before 2011 (Appendix B, Table 3.12). This was because fish was more abundant than the previous years and the number of fishermen increased, which brought about competition in selling fish. In addition, consumption demand of wild fish decreased, influenced by domestic fish culture which increased, and import of cultured fish with lower price from neighboring countries was also high. There were also many fish traders in markets that brought fish from everywhere in the country as well as imported cultured fish and competed with wild fish in the region.

Fish Farmers

Socio-demographic Characteristics of Fish Farmers

Eighty-five (85) percent of fish farmer households were male, while the rest were female. On average, the household respondents were aged 43 years, and ranged from 23 to 61 years. The majority age group of the respondents was 41 to 60 years with 50% for male, and 41 to 60 years with 12.5% for female (Appendix B, Table 3.13).

[*] Juvenile of commercially important fish species

The years of experience in fish farming was different by type of farming system and sex. On average, it was 9.5 years, ranging from 2 to 31 years. The respondents who practiced cage farming system had more years of experience (11.4 years) then those who applied pond farming system (6.1 years). Moreover, male respondents had higher experience in fish farming (9.9 years) than female did (7 years) (Appendix B, Table 3.14).

Fish Production Activities

There were only two types of fish farming systems practiced in the selected study areas. They were pond and cage fish farming systems. Nearly 80% of sampled fish farmer households practiced cage fish farming system, whereas more than 20% apply pond fish farming system. This was because most of the household respondents were living along and on the river where cage fish farming was more suitable in terms of location (They do not need land or large water surfaces, since some cages could be built underneath the floating houses) and condition (water level). Unlike this, some fish farmer households culturing fish in ponds had to concern about the land for building the pond leading to having more production costs and the water level of the river that might overflow into the pond (for the pond built near the river or water sources). According to the study, at least 17 fish species had been culturing by the sampled households. They were *Pangasianodon Hypophthalmus* (Pra Thom), *Pangasius Bocourti* (Pra Khchao), *Hemibagrus Wyckioides* (Khcha), *Wallagoattu* (Sanday), *Brachirus spp.* (AndatChhke), *Channa Micropeltes* (Chhdaur), *Clarias spp.* (Andeng), *Pangasius Conchophilus* (Kae/PraKae), *Pangasius Larnaudii* (Pou), *Leptobarbus Hoeveni* (Proloung), *Barbonymus Gonionotus* (Chhpin), *Barbonymus Schwanenfeldii* (KaHae), *Cirrhinus Microlepis* (Proul), *Osteochilus Melanopleurus* (Krum), *Henicorhynchus Siamensis* (Riel Tom), *Pseudolais Pleurotaenia* (Chhveat), *Cyclocheilichthys spp.* (Chhkork). In terms of numbers of fish farmer households, 5 of these fish species were commonly cultured, such as: Pra Thom, Chhdaur, Pra Khchao, Khcha and Kae/PraKae with 20.5%, 19.2%, 10.3%, 10.3%, and 10.3%, respectively (Appendix B, Table 3.15). Furthermore, in terms of quantity of fingerlings stocked, 4 fish species were practically cultured, including Andeng, Pra Thom, Ka Hae, and Chhpin, respectively (Appendix B, Table 3.16).

In general, fish farmer households had 1.1 ponds, or 1.7 cages per household. On average, the pond size is 12,306.4 m^3 and the cage size is 165.7 m^3 per household. With this size, fish fingerlings stocked in the pond were 41,400 heads, and in the cage were 13,792 heads per household per crop. Furthermore, number of crops or cycles of fish cultured in either pond or cage was similar, around 1 time per year. However, duration for fish cultured per crop in cage was longer (13.8 months/crop) than that in pond (9.8 months/crop) due to aforementioned reasons (Appendix B, Table 3.17). Normally, fish culture could be started in any month of the year, but in this study it was most preferably commenced in September.

Normally, the price of fingerlings varied in accordance with fish species and size of fingerlings/fish stocked in each type of farming system. The price differed by size of fingerlings/fish stocked due to the fact that the size of fish bought and applied into ponds and cages was different. In pond fish culture, only fingerlings were applied and started to be cultured until maturing time. In contrast, in cage fish culture, both fingerlings and juvenile fish (included as fingerlings in this study) were applied. On average, the price of fingerlings was USD 0.15 per head, ranging from USD 0.03 to 0.39 (Appendix B, Table 3.18).

Types of fish species selected for fish culture was not very much different. About 51% of fish farmer households chose hybrid fingerlings, while the rest chose the wild ones (Appendix B, Table 3.19). Percentage of supplying sources of fingerlings by fish species is shown in Appendix B, Table 3.20. According to the table, supplying sources of fingerlings included: own capture in nature, fishers, hatchery farms/stations, nursery sites, other fish farmers, and importers (from Vietnam and Thailand). Of these sources, nearly half of fingerlings were supplied by other fish farmers (46%), followed by own capture in nature (19.9%), fishers (15%), importers (12.4%), nursery sites (5.6%), and hatchery farms/stations (1.2%).

Types of Fish Feed Used

Types of basic feed used for fish culture included: freshwater small-sized fish in fresh and dried forms, marine small-sized fish, commercial/pellet feed, and rice bran. Besides this, there were additional feeds such as: bone and head of Pra, fish and chicken intestine, fish sauce germ, Kapok flour (Mor'saov kor), and vegetables like water spinach, etc. However, not all of these fish feeds were used by all fish farmers. Sometimes, only two or three types of fish feed were used, depending on its availability varied by time and season. When used, the feed was mixed and cooked together. Additionally, some types of the feed were given in fresh form when abundant (e.g. freshwater small-sized fish). Of these various feed types, probably 45% of fish farmer households used freshwater small-sized fish, followed by rice bran (27%), marine small-sized fish (13.5%), and commercial/pellet feed and others (14.6%) (Appendix B, Table 3.21). On average, volume of feed used for fish culture was 54,686.4 kg per crop. Most of the feed used was freshwater small-sized fish (fresh and dried) (31%), followed by rice bran (20%), commercial/pellet feed (19%), marine small-sized fish (17%), and others (bone and head of Pra, fish and chicken intestine, fish sauce germ, Kapok flour, and water spinach) (13%) (Appendix A, Figure 3.22).

Commonly, feed used for fish culture was either self-supplied or bought from markets. Some types of fish feed could be caught and found by the household themselves, including freshwater small-sized fish, rice bran, and others (bone and head of Pra, fish and chicken intestine, fish sauce germ, Kapok flour, and water spinach). They were half self-supplied and half bought from markets. Nevertheless, some types of feed such as marine small-sized fish and commercial/pellet feed were totally bought from markets. Therefore, overall, 30% of the feed used for fish culture was self-supplied by fish farmers, while 70% was bought from markets (Appendix B, Table 3.23).

Trend of the Use of Fish Feed for Fish Farming

Trends of type of fish feed, and quantity and price of freshwater small-sized fish used for fish culture over the past 5 years were asked in order to understand the changes and the development of freshwater small-sized fish used as fish feed. Appendix, Table 3.24 revealed the trend of types of fish feed used for fish culture over the past 5 years. According to the table, the use of type of fish feed was mostly unchanged (72.5% of fish farmer households) because number of fish culture was the same and fish farmers did not expand their culture. Additionally, only these few types of feed could be locally and commonly found and eaten by the fish.

There was a similarity between the numbers of fish farmer households responding that quantity of freshwater small-sized fish used for fish culture over the past 5 years was increased and unchanged, with 40% and 37.5% of fish farmer households, respectively (Appendix B, Table 3.25). The increased use of freshwater small-sized fish resulted from the abundance of the fish, particularly during last open season (2011-2012).

Trends of price of freshwater small-sized fish for fish culture over the past 5 years was decreased (57.5% of the household respondents) for several reasons (Appendix B, Table 3.26). First of all, it was the quantity of fish. Compared to the previous years, freshwater small-sized fish was more abundant. Moreover, numbers of fish farmers decreased recently, so demand on the fish for fish feed was also decreased. Furthermore, there seemed to be a decline of human consumption on freshwater small-sized fish, making the fish that was already abundant become even more so and the price of freshwater small-sized fish was consistently decreased.

Fish Traders

Socio-demographic Characteristics of Fish Traders

More than half of the sampled fish traders were male. The average age was 41 years, ranging from 20 to 66 years. The majority age group of the respondents was 20 to 50 years with 44% for male and 38% for female. (Appendix B, Table 3.27).

Overall, fish traders had an average of about 15 years of experience in fish trade, ranging from 1 to 50 years. The average years of experience was very similar among types of fish traders (collectors/middlemen, wholesalers, and retailers). Normally, females had more years of experience (16 years) in fish trade than males did (14.6 years) (Appendix B, Table 3.28).

Trading Activities of Freshwater Small-sized Fish

The study showed that fish trade took place at home, landing site, local market, bag net (Dai), fish sauce factory, or no mantic. These places were chosen based on condition and suitability of the trade, and types of traders. For instance, fish collectors/middlemen commonly traded fish at home where fish were directly brought and sold to them. However, there were also a few cases that they traded fish at landing sites or local markets. Furthermore, while most of collectors/middlemen did fish trade at home, wholesalers mostly traded fish at landing sites and retailers traded fish at local markets.

Nearly all of fish trade took place without any agreement or contract because, most of the cases, they thought that it was free markets, and not a habit. Moreover, in some condition, because some traders lived very far from the trading places and the quantity of demanded fish was much, an agreement or contract could not possibly be made. And, after fish was traded, money was given immediately, so it was not necessary to sign an agreement or contract. Nonetheless, very few of fish trader household respondents had an agreement or contract in their business. Of those, only 1 household respondent had a contract via hand-writing, and besides this, the contract was done orally due to trust.

Volume, Species and Price of Fresh Freshwater Small-sized Fish

Trade of fresh freshwater small-sized fish varied by season, mainly during open and closed seasons. On average, freshwater small-sized fish were traded 6 months per year with 20.5 days per month. However, they were sold every month in closed season with almost 20 days per month. In other words, it was sold 8 months per year with around 20 days per month. Rate of weight loss of fresh freshwater small-sized fish traded in all seasons was estimated about 4% of the total volume.

On average, volume of freshwater small-sized fish traded was 1,922 kg per day. It was different by season. During open season, volume of the fish traded was high, up to 2,001 kg per day. However, during closed season, it was only 57 kg per day (Appendix B, Table 3.29).

At least 38 species of freshwater small-sized fish (including juveniles of commercially important fish species mixed with small-sized fish when bought) was presented in the trade. The top 10 fish species in terms of volume traded in 2011-2012 were: *Henicorhynchus spp.* (Riel) (1,415.3 kg/day), *Thynnichthysthynnoides* (Linh) (907.2 kg/day), *Paralaubucariveroi* (Sleuk Reussey) (617.8 kg/day), *Clupeichthys spp.* (BandolAmpov) (550.4 kg/day), *Labiobarbus spp.* (Ach Kok) (543.5 kg/day), *Parachela spp.*(ChanteasPhlouk) (302 kg/day), *Cirrhinusmicrolepis* (Kralang[*]) (234.5 kg/day), *Kryptopterusmoorei*(Komphleav) (133.7 kg/day), and *Parambassis spp.* (Kanhchanh Chrass)

[*] Juveniles of commercially important big-sized fish species

(118.7 kg/day) (Appendix B, Table 3.30). Availability and abundance of each species of freshwater small-sized fish was different by time in open season, especially in peak period, and by place.

Price of freshwater small-sized fish varied depending on species, its abundance, and how it was sold. Thus, it was always changing by season, and ranged from USD 0.2 to 1 per kg in all season (Appendix B, Table 3.31). Each species consisted of its own value, but some species had the same commercial value when they were mixed and sold together, particularly during peak period of open season. During low period and closed season when the fish was scarce it was mostly sold separately by species or sometimes beheaded before being sold, making its price a little bit higher.

Trend of Fresh Freshwater Small-sized Fish Traded

Volume of fresh freshwater small-sized fish traded was increased by 50% of the sampled household respondents during 2011 - 2012 compared to that before 2011. However, size, quality and information on fish selling (fish price) and consumption (demand on fish) was unchanged with 68%, 54%, and 48% of the respondents, respectively. In addition, price of fish and convenience in selling fish was decreased with 64% and 50% of the respondents (Appendix B, Table 3.32)

The respondents were asked to give marks from 1 to 10 (1-4: not good; 5: medium; and 6-10: good) to some factors related to fish trade in order to know condition and improvement in the trade. The factors included: fish species, volume, size, price, quality, distance for the trade, convenience in loading fish, packaging, support given by sellers/buyers, and behavior of sellers and buyers. The study revealed that all the above factors, accept volume and price of fish, were given number 5 indicating that all these factors was neither good nor bad for the respondents. However, they marked number 6 to the volume of fish meaning good because fish was more abundant than the previous years, but they gave number 4 to the price of fish due to the fact that the price was decreased resulting from the abundance of fish. Therefore, they found it difficult to sell the fish.

Volume, Type and Price of Processed Freshwater Small-sized Fish

More than three-quarters of the sampled fish traders processed freshwater small-sized fish remaining from selling into various types of products.

Overall, processed freshwater small-sized fish was traded nearly 10 months per year in which 7 months in open season and 3.4 months in closed season. An average number of days trading fish was 23.3 days per month, ranging from 23.6 days in closed season to 24.7 days in open season.

Only processed products from freshwater fish (all species) was sold by the sampled fish traders.
On average, volume of processed freshwater fish traded was 57.2 kg per day, of which 56.2 kg was processed freshwater small-sized fish. Volume of the processed small-sized fish traded was changing by season and thus it was sold in larger quantity in open season which was about 57 kg per day while in closed season it was only about 27 kg per day (Appendix B, Table 3.33).

There were 4 types of processed freshwater small-sized fish being sold by the sampled fish traders in markets. Those products were: salted-dried fish (Trey Brolark), smoked fish (Trey Chha'eur), fermented fish (Pha'ork), and fermented fish paste (Pro'hoc). Fermented fish paste was most commonly traded (39.5 kg/day) due to the fact that it was most preferably consumed by Cambodian people, compared to other processed products such as fermented fish, smoked fish, and salted-dried fish, which was traded only 24 kg, 10.2 kg and 5 kg per day, respectively. (Appendix B, Table 3.34).

Price of processed small-sized fish was different by type of products and season. On average when bought, salted-dried fish was priced USD 0.5 per kg, smoked fish USD 4.1 per kg (or USD 0.31 per skewer; 1 skewer = 7.5 g or 0.075 kg), fermented fish USD 0.8 per kg, and fermented fish paste USD 0.8 per kg. However, when sold, salted-dried fish was valued USD 0.8 per kg, smoked fish USD 4.4 per kg (or USD 0.33 per skewer), fermented fish USD 1.5 per kg, and fermented fish paste USD 1.1 per kg (Appendix B, Table 3.35). Among these products, fermented fish was more returnable (USD 0.7/kg) compared to other products (USD 0.3/kg).

Trend of Processed Freshwater Small-sized Fish Traded

If compared to the previous years (2010 - 2011), volume of processed freshwater small-sized fish traded during 2011 - 2012 was decreased by 41.7% of the household respondents. This was because freshwater small-sized fish was more abundant. Therefore, some people who liked consuming fish processed products could process fish by themselves, making volume of the processed fish sold in markets decline. Nevertheless, size, price and quality of the processed small-sized fish remained unchanged up to the present. In addition, convenience in trading, and information on selling (price) and consumption (demand) on processed freshwater small-sized fish was increased by 75% and 58.3% of the household respondents, respectively (Appendix B, Table 3.36).

The household respondents were asked to give marks from 1 to 10 (1-4: not good; 5: medium; and 6-10: good) to some factors related to the trade of processed freshwater small-sized fish in order to know condition and improvement in the trade. The factors included: fish species, volume, size, price, quality, distance for the trade, convenience in loading the products, packaging, support given by sellers/buyers, and behavior of sellers and buyers. The study showed that fish species, volume and packaging of the products and behavior of sellers/buyers when selling and buying the products was marked good for 50% to 75% of the household respondents. Nevertheless, fish size, price and quality of the products, distance/place for trading, convenience in loading the products, and support given by sellers and buyers was scored medium by 33.3% to 83.3% of the respondents.

Fish Exporters

Socio-demographic Characteristics of Fish Exporters

Sixty (60) percent of the sampled fish exporters exported freshwater small-sized fish in fresh form, while 40% exported in processed form.

Overall, more than half of the exporters were female. The respondents had an average age of 42 years, ranging from 30 to 57 years. The majority age group was from 31 to 60 years, with 40% for male and 40% for female respondents (Appendix B, Table 3.37).

On average, the household respondents had experiences in fish export 13 years, ranging from 5 to 26 years. Of this, they had been involving in the export of freshwater small-sized fish for about 12 years, ranging from 5 to 23 years. Overall, males had more year experiences (15.5 years) in the business than females did (11.3 years) (Appendix B, Table 3.38).

Exporting Activities of Fresh Freshwater Small-sized Fish

Over half of fish exporters exported fish only in open season because fish was abundant at that time and they respected fisheries law. However, fewer than 50% exported fish in both the open and closed seasons because fish was abundant and there was a surplus in domestic markets. Moreover, they exported fish in the closed season in order to get more profit, since the exported fish could be sold at a high price and was exported by species only.

All of fish exporters held loading and exporting licenses. Nevertheless, nearly all of them did not have agreements or contracts in their business because they thought that it was neither a habit nor a necessity. Additionally, the fish was paid for in cash as soon as it was bought. Of the household respondents, only 1 respondent had an oral agreement or a contract in their business with fish collectors/middlemen. The contract usually lasted for 14 days.

According to the study, volume of fish allowed for export varied by types of products. Generally, fresh fish could be exported at the volume of 2,500 kg per time, ranging from 2,000 to 3,000 kg. Furthermore, processed fish was allowed for export at 15,000 kg per time, ranging from 10,000 to 20,000 kg.

Volume, Species and Price of Fresh Freshwater Small-sized Fish

Fresh freshwater small-sized fish was exported every month of the year. However, number of days or times for the export was different by season. Fish was exported most often in the peak period of open season, which was up to 22.7 days or times per month. In low period, it was only 5.7 days per month. Therefore, it could be assumed that fish was exported about 13 days per month during open season, and 8 days per month during closed season. Thus, on average, fish was exported 11.8 days per month, annually.

On average, volume of fresh freshwater small-sized fish exported was 1,527 kg per day (57% of fresh freshwater fish exported per day at the same time). In open season, it was exported 1,556 kg per day, and in closed season it was exported 50 kg per day. Fresh freshwater small-sized fish was largely exported in peak period 1,900 kg per day (60% of freshwater fish exported per day at the same time), but least exported in closed season 50 kg per day (20% of freshwater fish exported per day at the same time) (Appendix B, Table 3.39).

Approximately 10 species of freshwater small-sized fish (including juveniles of big-sized fish) were exported every year. Those species included: *Henicorhy* (Riel), *Mystus spp.* (Kanchos), *Trichogaster spp.* (Kompleanh), *Yasuhikotakia spp.* (Kanchrouk), *Kryptopterusmoorei* (Kompleav), *Coilia spp.* (Chunlournh Morn), *Puntioplites spp.* (Chrokeng[*]), *Acantopsis spp.* (Reus Chek[*]), *Macrognathus spp.*(Chhlonh[*]), and *Notopterusnotopterus* (Slat[*]). Of these 10 species, Kompleanh, Kanhchos, Reus Chek[*], Kanhchrouk, Chunlourn Morn, and Chrokeng[*] with 891 kg, 624 kg, 534 kg, 447 kg, and 446 kg per day, respectively, were the most commonly exported (Appendix B, Table 3.40). Furthermore, there were only 2 fish species, Kompleav and Slat[*], were exported during closed season.

By excluding juvenile fish species, on average, price of freshwater small-sized fish ranged from USD 0.23 to 1.75 per kg. Of the 10 species, Kompleav obtained the highest commercial value of USD 1.75 per kg, followed by Kanhchrouk (USD 0.76/kg), Kanhchos (USD 0.50/kg), Riel (USD 0.38/kg), and Kompleanh (USD 0.30/kg) (Appendix B, Table 3.41).

Trend of Fresh Freshwater Small-sized Fish Exported

The study showed that volume of fresh freshwater small-sized fish exported grew (66.7% of the household respondents) in 2011-2012 compared to that before 2011. However, price of fresh freshwater small-sized fish was decreased (66.7%), resulting from the abundance of fish and leading to the decrease in convenience in exporting fish (66.7%) because fish exporters found it hard to sell their fish when the price was declined. Nevertheless, there were many things remaining stable such as fish size (66.7%), fish quality (100%) and information on exporting fish (market demand and price) (66.7%) (Appendix B, Table 3.42).

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[*] Juvenile of commercially important fish species

Volume, Type and Price of Processed Freshwater Small-sized Fish

Normally, export of processed freshwater small-sized fish was done only 5 months per year with 12.4 days per month. The period for the export was varied by season. In open season, it was 4.5 months (from December to April) with 13.5 days per month. Nevertheless, in closed season, it was only 1 month (June) with 2 days per month.

There were 2 types of processed freshwater small-sized fish that were exported: salted fish (Trey Brolark) and fish paste (Pro'hoc). These products were not exported together by the same exporters. More clearly, one fish exporter exported only one type of products. In term of exported volume, salted fish was the most commonly exported product compared to fish paste. On average, the exported volume of processed freshwater small-sized fish was 14,792 kg per day. The average exported volume of salted fish was 19,584 kg per day, and fish paste was 10,000 kg per day. The exported volume could be varied by season. In open season, it was 15,000 kg per day and in closed season it was 4,000 kg per day (Appendix B, Table 3.43). During closed season, only salted fish was exported.

On average, price of fish paste was a little bit higher than that of salted fish. Fish paste was priced at USD 0.55 per kg. However, salted fish was priced at USD 0.48 per kg, ranging from USD 0.45 per kg in the open season to USD 0.50 per kg in the closed season (Appendix B, Table 3.44).

Trend of Processed Freshwater Small-sized Fish Exported

Compared to before 2011, the size and quality of processed freshwater small-sized fish exports remained unchanged. However, the price and convenience in exporting the processed fish declined at the same time that volume and information on trading and consuming the processed fish (price and consumption demand) increased.

Fish Processors

Socio-demographic Characteristics of Fish Processors

Overall, more than 60% of the sampled fish processors were female. The average age of the household respondents was 51.4 years, ranging from 31 to 70 years. The majority age group of the respondents was between 41 to above 61 years (80.9%). Of this, the majority age group of male was 61 and above with 18.2%, and of female was 41 to 50 years with 45.5% (Appendix B, Table 3.45).

On average, fish processors had 16.8 years of experience in fish processing, ranging from 6 to 32 years. Female processors had more years (18 years) in fish processing than males did (15 years) (Appendix B, Table 3.46).

Fish Processing Activities

Fish processing activities were commonly done without any agreement or contract by nearly three-quarters of fish processor household respondents, because they found that it was not a habit while the business and everything now was done in free markets. Furthermore, they thought it was not necessary to do so. Nonetheless, more than one-third of the household respondents had an agreement or a contract in their business in most cases through handwriting, and least via oral agreement. This contract was done with wholesalers and collectors/middlemen, respectively, with an average duration of 23.3 days.

There were 5 types or forms of fish products preserved from freshwater small-sized fish commonly found, including: salted-dried fish (Trey Brolark), smoked fish (Trey Chha'oeur), fish sauce (Teuk Trey), fermented fish (Pho'ork), and fish paste (Pro'hoc).

Overall, number of months and days in fish processing activities could be different by types or forms of processed products. On average, fish processor household respondents were involved in fish processing 5.7 months per year, ranging from 2.5 to 12 months. Mostly, they processed fish from November to March when freshwater small-sized fish was available and abundant for processing. Furthermore, on average, they processed fish only 18.7 days per month, ranging from 9 to 30 days. Additionally, time of one processing cycle also varied by product but on average it was 30.7 days per time or cycle, which ranged from 1 day up to 2 months per time or cycle (Appendix B, Table 3.47).

Raw Materials Used for Fish Processing

Besides freshwater fish (both small and big-sized fish), other raw materials used for fish processing included: salt, sugar and gram. According to the study, 358,360 kg of raw materials were used for fish processing per year. Of this volume, 208,400 kg were from freshwater small-sized fish (Appendix B, Table 3.48).

On average, around 145,286 kg of freshwater small-sized fish was bought by processor household respondents for processing every month. With this volume, some of 13 fish species were presented, such as: *Henicorhynchus spp.* (Riel), *Mystus spp.* (Kanhchos), *Trichogaster spp.*(Komphleanh), *Thynnichthysthynnoides* (Linh), *Clupeichthys spp.* (Bandoul Ampov), *Yasuhikotakia spp.* (Kanhchrouk), *Osteochiluslini*(Kros), *Paralaubucariveroi* (Sleuk Reussey), *Cyclocheilichthys spp.* (Chhkok*), *Labiobarbus spp.* (Ach Kok), *Coilia spp.* (Chunlournh Morn), *Pteropangasiuspleurotaenia* (Chhveat), and *Parachela spp.* (Chunteas Phlouk). In term of buying volume, the most common ones were Riel (112,654 kg/month), Linh (90,000 kg/month), Kompleanh (79,719 kg/month), Sleuk Reussey (15,620 kg/month), and Ach Kok (15,000 kg/month). However, not all of these species were bought by the same processors or at the same time. In addition, an average price of these fish species ranged from USD 0.25 (Kanhchos, Linh, Kanhchrouk, Ach Kok, and Chunteas Phlouk) to 0.75 (Chhveat) per kg (Appendix B Table 3.49).

Selling of Processed Freshwater Small-sized fish

With the total volume of 358,360 kg of raw materials, including fish, used for processing per year, each fish processor household could receive 237,448 kg of final or finished processed products per year. Of this volume, 210,957 kg were final processed freshwater small-sized fish products (Appendix Table 3.48). If considered by type of the processed products, on average, volume of fish sauce^Δ produced by a processor household/factory was 900,000 L (L equal kg) per year. Moreover, an average volume of salted-dried fish^Δ produced was 242,467 kg per year, of fish paste^Δ was 113,729 kg per year, of fermented fish^Δ was 17,800 kg per year, and of smoked fish^Δ was 7,100 kg per year (Appendix B, Table 3.50).

Overall, the number of months in which processed freshwater small-sized fish was sold varied by type of processed products. On average, it was 7.6 months per year, ranging from 2.5 months for smoked fish to 12 months for fish sauce. Furthermore, the average time of selling all processed products were 17.1 times per month, ranging from 16.6 times for fish paste to 25 times for fermented fish and fish sauce. This

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* Juvenile of commercially important fish species

Δ Conversion ratio of freshwater small-sized fish from fresh into processed forms:

- **1**:**0.5** for salted dried fish
- **1**:**0.075** for smoked fish
- **1**:**0.4** for fermented fish
- **1**:**0.3** for fish paste
- **1**:**3** for fish sauce

meant that fish sauce was produced and sold out every month and nearly every day of the month, compared with other types of processed products. Moreover, volume of all processed products sold per time could be different but averaged to 5,158 kg per time. Fish sauce was the most commonly sold out processed product, with an average of 8,000 L per time, compared to fish paste, smoked fish, fermented fish and salted-dried fish with 6,661 kg, 559 skewer, 426.7 kg, and 175 kg, respectively. In addition, price of the processed products was very similar for salted-dried fish, fermented fish and fish paste (around USD 1/kg), except smoked fish (USD 0.3/skewer) and fish sauce (USD 0.5/L) (Appendix B, Table 3.51).

Trends of Freshwater Small-sized Fish Processing

Trends of processing activities of freshwater small-sized fish were divided into 2: the trend of raw materials (fresh small-sized fish) used for processing and the trend of final processed products. Respondents were asked to compare processing activities this year (2011-2012) with that before 2011.

According to the study, there were more varieties of raw materials (freshwater small-sized fish) that could be used for producing many types of processed products of freshwater small-sized fish (33.3% to 100% of the respondents). This growth resulted from the abundance of fish with low prices, which was the consequence of recent fisheries reform (abolishing all fishing lots) and fisheries law enforcement. Moreover, supply and demand on raw materials for producing smoked fish, fermented fish and fish paste has gradually increased recently (100%) because fish, particularly small-sized fish increased and the number of fish suppliers like fishermen and fish collectors/middlemen also increased. However, it remained unchanged for supply and demand on fresh and salted-dried fish (44.4% to 66.7%). Notably, volume of raw materials used for producing each processed product increased (33.3% to 100%) (Appendix B, Table 3.52). This was because small-sized fish was more abundant. Fishers could catch more fish, making the price of fish for processing low and fish processing increased. As long as the price of processed fish decreased, market demand on processed fish increased because of its better quality.

From 37.5% to 100% of the respondents revealed that type of processed products of freshwater small-sized fish, mainly fish paste, salted-dried fish and smoked fish decreased, while 37.5% to 100% more said that type of products including fish paste, salted-dried fish and fermented was stable. Type of fish processed products declined due to the fact that not many processors were willing to process more since its price was low, so it was very difficult to sell the products. Also, it was difficult to find laborers to serve in the workforce since many of them migrated for work to other provinces or countries. Moreover, regarding type of products, only fish sauce was reported increased by 100% of the respondents because freshwater small-sized fish was abundant and bought at low price. Also, supply and demand on the processed products was reported decreased for salted-dried fish, smoked fish and fermented fish paste (50% to 66.7% of the respondents), but it was unchanged for fish paste (50%) and increased for fish sauce (100%). Furthermore, volume of the processed products, especially salted-dried fish, fish paste, smoked fish and fermented fish was dramatically declined (50% to 100%) because price of the processed products decreased (resulting from abundance of fish) and processors reduced volume of processing to avoid a loss. Nevertheless, volume of fish sauce still kept on increasing (100%) (Appendix B, Table 3.53).

Fish Consumers

Socio-demographic Characteristics of Fish Consumers

Overall, an average age of fish consumers was 44 years, ranging from 19 to 76 years. More than half of them were female. The majority age group was between 31 to 60 years (76%), with 40% for male and 36% for female (Appendix B, Table 3.54).

Volume and Preferable Fish Species and Products

In this study, two different types of consumers – fishermen and non-fishermen – were selected. Volume of freshwater small-sized fish consumed (both fresh and processed forms) was varied by type of consumers and by provinces. On average, volume of freshwater small-sized fish consumed by fishermen in all provinces was higher (231 kg per year per household) than that consumed by non-fishermen in all provinces (195.8 kg per year per household). Therefore, regardless of type of consumers, an average volume of freshwater small-sized fish eaten was 213.4 kg per year per household, ranging from 19 to 921 kg. This volume was found the highest in Phnom Penh with 267.7 kg per year per household, and the lowest in Battambang province with 107.4 kg per year per household (Appendix B, Table 3.55).

Many fish consumers revealed their own preferences in fish species differently. However, in most of the cases these species were ranked into 5 categories. Number 1 referred to the most preferable fish species and number 5 referred to the least preferable fish species. The study showed that of the species of freshwater small-sized fish, *Henicorhynchus spp.* (Riel) got number 1 which meant the most preferable fish species, followed by *Mystus spp.* (Kanchos), *Opsariuskoratensis* (Changva), *Trichogaster spp.* (Kompleanh), and *Anabas testudineus* (Kranh), respectively. There were many reasons to prefer such fish species, one of which was low price. Another thing, it was delicious and low fat which could be cooked into many dishes, and free from chemical substance that would affect human health. Furthermore, it provided more nutrition for development of the human body and brain. More importantly, it was easy to buy since fishermen could catch it every day.

Types of processed products from freshwater small-sized fish consumed including fresh fish, salted-dried fish (Trey Brolark), smoked fish (Trey Chha'oeur), fermented fish (Pho'ork) and fish paste (Mam/Pro'hoc). Fresh fish was the most preferably consumed form of fish compared to other types/forms of fish. It was followed by fish paste, smoked fish, salted-dried fish and fermented fish, respectively (Appendix B, Table 3.56).

Consumption on Freshwater Small-sized Fish

Normally, the number of days and times fish consumers bought each type of freshwater small-sized fish products depended on how much they consumed and relied on it, or how much it was important and affordable for them. The study showed that fish consumers bought freshwater small-sized fish products every 3.8 days (for fresh fish) to 104 days (for fish paste) per time. An average buying volume was varied by product, which was 0.7 kg per time for fresh fish, 0.7 kg per time for salted-dried fish, 3.1 skewers per time for smoked fish, 5.7 kg per time for fermented fish, and 7.6 kg per time of fish paste. An average distance to buy these products ranged from 116.6 to 231 m away. On average, the price of fresh fish and salted-dried fish was the same, which was USD 0.9 per kg. This was because salted-dried fish was normally processed from not-so-fresh fish with smaller size. Furthermore, the price of smoked fish was USD 0.3 per skewer; the price of fermented fish was USD 1.6 per kg; and the price of fish paste was USD 1.7 per kg (Appendix B, Table 3.57). The price of these processed products might be higher from June to September when freshwater small-sized fish were scarce, but could be lower from November to March when freshwater small-sized fish were abundant.

Fish consumers were asked to provide scores from 1 to 10 (1-4: bad; 5: medium; 6-10: good) to consumption on freshwater small-sized fish in both fresh and processed forms. The result indicated that over half of them (55.3%) marked from 6 to 10, meaning that freshwater small-sized fish consumed was good.

Beyond this, fish consumers were also posed to mark from 1 to 10 on some factors in order to reveal their opinion when they bought and consumed fresh and processed freshwater small-sized fish. Those factors included fish species, quantity, size, price, distance/place to buy the products, convenience in buying the products, packaging of the products after bought, support given by fish sellers, and sellers' behaviors. The result showed that fish species, size, distance/place to buy the products, packaging and support given by sellers was just medium for them. However, they thought that fish quantity (more abundance), price (low), convenience in buying fish (since the price was low, it was easy to buy fish), and behaviors of the sellers were quite good.

Trend of Consumption of Freshwater Small-sized Fish

Overall, more than 50% of consumer household respondents thought that the quality, convenience and information on the supply and use of freshwater small-sized fish in both fresh and processed forms was medium. However, only fresh freshwater small-sized fish was considered good in convenience in consuming by most of the household respondents (Appendix B, Table 3.58).

Comparing the consumption of freshwater small-sized fish and its processed products in 2011-2012 to that before 2011, it was seen that buying volume, fish size, quality, convenience in consuming fish, and information on the supply and use on fish was unchanged (by 52.7% to 70.2% of the respondents). However, the price of fish was decreased (43.1%), except smoked fish, which remained unchanged (51.3%) (Appendix B, Table 3.59).

Value Chain Analysis and Marketing Channel of Freshwater Small-sized Fish

Fishermen

There were many ways in which fishermen could sell their fish. They could: 1) carry the fish to markets and sell it directly to end consumers, 2) carry the fish to landing sites and sell it to fish collectors/middlemen/wholesalers, 3) sell the fish to fish collectors/middlemen/wholesalers at fishing grounds, 4) bring the fish to the villages and sell it to fish collectors/middlemen/ wholesalers, or 5) sell the fish directly to neighboring consumers at home. According to the study, 73.4% of fisher household respondents chose ways number 2, 3 and 4, respectively, to market their fish, whereas only 26.6% chose ways number 1 and 5 (Appendix B, Table 3.60).

Before being sold, fish was partly kept for household consumption (fresh and processed forms) 3.2% of total volume of fish caught per year. It was then sold to various types of buyers including local fish collectors/middlemen/traders (25.6%), processors (21.7%), end consumers (18%), fish collectors/middlemen/traders from other provinces (15.9%), fish and animal farmers (fish/ animal feed) (14%), and exporters (1.6%) (Appendix B, Table 3.61).

Trend of freshwater small-sized fish distribution (numbers of buyers and buying volume) was reported unchanged by 50.4% of fisher household respondents. However, 37.8% of them said the trend was increased, while 11.9% said the trend was decreased (Appendix B, Table 3.62).

Fish Traders

As mentioned above, two types of fish forms - fresh and processed - were traded by fish traders in this study. Therefore, supplying and demanding sources of each form of fish might be different, to some extent.

Supplying sources of fresh fish encompassed fishers, fish collectors/middlemen and wholesalers. Moreover, some fish traders could catch fish by themselves, but volume of fish caught (8.4% of total volume traded per year, (2011-2012) was less than volume of fish bought from the above sources. Annually, 33.6% of volume of fish traded was bought from fishers, 32.7% from fish collectors/middlemen, and 25.4% from wholesalers (Appendix A, Figure 3.2). Of the various sources, fishers were considered the most important because they were permanent fish suppliers for fish traders throughout the whole year. Furthermore, fish sold by fishers was fresh and of good quality. Traders felt it easy to buy fish from fishers and the fish was bought at lower price than that bought from fish collectors/middlemen/wholesalers. Additionally, it was easy to order fish from fishers, since they were loan borrowers and thus obliged to sell fish to the traders (loan providers). In addition, they were living near fishers' houses, so it was much easier to buy fish from them. Nevertheless, for some traders buying fish from bag nets/dai operators illustrated that bag net operators were their only main fish suppliers due to the recent cancellation of fishing lots and no other large fishing gears could be used for catching the fish, except bag nets.

Most of the fish bought was retailed to end consumers (25.6%). Also, it was sold to processors 19.2%, local retailers 17.7%, fish collectors/middlemen/wholesalers 15.2%, fish and crocodile farmers and animal feed processors 15.2%, and exporters 7.1% (Appendix A, Figure 3.3). Of these demanding sources, only end consumers and local retailers were regarded the most important because they were permanent buyers; fish was sold with immediate payment in cash; and fish traders could obtain higher profit (fish was priced the last stage of payment).

Processed freshwater small-sized fish sold was either processed by fish traders themselves or bought from others. In the case that it was processed by traders, the supplying sources of fresh fish for processing were fishermen (45.2% of total volume of fresh fish bought for processing), fish collectors/middlemen (38.4%) and wholesalers (16.4%) (Appendix A, Figure 3.4). However, in case that they did not process fish by themselves, the supplying source of the processed products was processors.

Processed freshwater small-sized fish included salted-dried fish, smoked fish, fermented fish and fish paste. Buyers of these processed products could be collectors/middlemen/wholesalers, local retailers and end consumers. Overall, around 43% of the products were sold to collectors/ middlemen/wholesalers, 34% to local retailers, and 23% to consumers (Appendix B, Table 3.63).

Fish exporters

Like fish traders, two types of fish forms – fresh and processed forms – were exported by fish exporters. There were only two supplying sources of fresh freshwater small-sized fish, including fishermen and fish collectors/middlemen. More than half of the fresh fish (60%) was supplied by fish collectors/middlemen, whereas less than half (40%) was supplied by fishermen (Appendix A, Figure 3.5). The important supplying source of fresh fish was fish collectors/middlemen because fish was brought in place (exporting companies), so fish exporters did not need to go further or hire laborers to collect fish from those collectors/middlemen or fishermen. Moreover, the fish selling price by those collectors/middlemen was lower than the market price since those collectors/middlemen borrowed money from exporters and had to sell fish to the exporters.

All the fish was then transported and sold to Thai fish collectors/middlemen (66.7% of the total exported volume) and to Thai wholesalers (33.3%) at Cambodia-Thailand land border point. Next, the fish was loaded by these collectors/middlemen and wholesalers into Thailand before distributed to some markets and restaurants in that country.

There were two types of processed freshwater small-sized fish such as salted fish and fish paste. Supply sources of these processed products were processors and collectors/middlemen. All of he salted fish was bought from collectors/middlemen, while all of the fish paste was bought from processors. After purchase, the products were transported and sold to Thai middlemen at the countries border point before entering Thailand.

Fish processors

Fishers, fish collectors/middlemen and other fish processors were supplying sources of fresh freshwater small-sized fish for processing. Of these various sources, about 75% of the total buying volume was from collectors/middlemen, followed by other fish processors (19%) and fishers (6%) (Appendix B, Table 3.64).

All processed products from freshwater small-sized fish, except fish sauce, were proportionately kept for household consumption (0.5% to 5% of the total production volume). The rest was sold to different types of buyers including collectors/middlemen, wholesalers/retailers, other fish processors and end consumers. The study showed that nearly all of salted fish (86%) and smoked fish (99%), and all of fish sauce (100%) were sold to wholesalers/retailers. Moreover, almost all of fermented fish was sold to collectors/middlemen (49.9%) and wholesalers/retailers (49.6%). Furthermore, nearly 90% of fish paste was sold to wholesalers/retailers (37%), collectors/middlemen (28%) and end consumers (24%), respectively (Appendix B, Table 3.65).

Fish consumers

Supplying sources of freshwater small-sized fish to end consumers were fishers, retailer processors, own catch (fresh fish) and own process (processed fish). These sources could vary by forms (fresh and processed forms) and type of processed products. However, generally, most of the products (fresh and processed) consumed was bought from retailers (30%), followed by fishers (23%), own processed (23%), processors (16%), and own catch (8%) (Appendix B, Table 3.66).

Figure 3.6 shows mapping of the value chain of freshwater small-sized fish in the LMB of Cambodia. Freshwater small-sized fish was both traded in domestic markets and exported (fresh and processed) to neighboring countries – Vietnam and Thailand. Of the total volume of the small-sized fish in the chain, 2.2% was exported to the above two countries, while 97.8% was traded in domestic markets. 3.2% of the fish was kept by fisher households for consumption. Fish collectors/middlemen/wholesalers played an important role by buying 41.5% of the fish from fishers before selling on to various combinations of other chain actors, including processors and retailers. Processors handled an estimated 30.5% of the fish in the chain. Moreover, less than 20% of the fish was directly retailed by fishers to end consumers. 14% of the fish was directly sold by fishers to fish/animal/crocodile farmers. 1.6% of the fish was sold to Vietnamese processors living in the area, and would be then exported to Vietnam by these processors. Of the total volume of the fish in the chain, around 73% was used for human consumption, whereas about 24% was used as feed for fish, animals and crocodile culture in the country. This figure was not very different from a study done by So et al. (2007) which revealed that around 85% of the total dai freshwater small-sized fish production in 2006-2007 in Tonle Sap River was locally utilized for human food in both fresh and processed forms, and for fish/animal feed; the rest was exported, in particular to Vietnam in both fresh and half-processed forms for human consumption and animal feed, respectively.

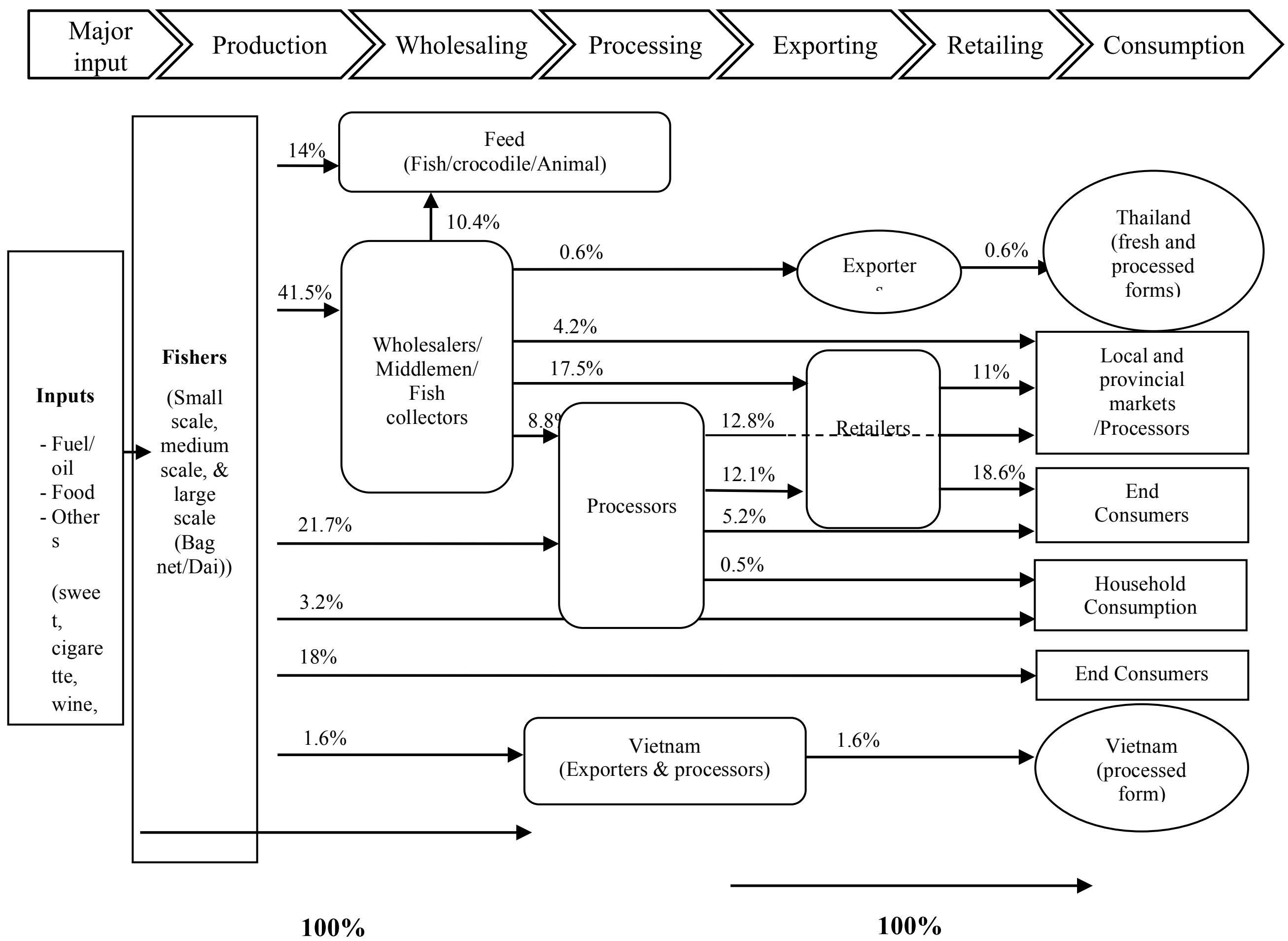

Figure 1. *Mapping of the value chain of freshwater small-sized fish in the LMB of Cambodia.*

Perception and Business Plan and Challenges/Constraints of Chain Actors

Perception and Business Plan

Fishermen

Fishing activity was considered a primary occupation of fishermen. It was a job that did not require much capital or much skill/knowledge. It was such a good opportunity that they were living near fishing grounds where they could go fishing all the time without spending much time and much cost on the trip. Besides keeping and processing the catch for household consumption, fisher households could take some advantages by selling the surplus for income to support their families, to send their children to school and to pay for medical care. Additionally, the fish could be used as fish feed by fisher households who cultured fish and this could reduce some parts of expenses on fish feed.

Fish Traders

Fish trade was considered easy work because it did not need much capital investment and the traders could get more profit. Most of them could earn more income to support their families. As reported, it was rarely lost because the fish left over from being sold could be processed for the next sale or even used as fish or animal feed. And, it was a great opportunity for some traders living near or along fishing grounds and fish supplying sources where the trade from everywhere was gathered. As a result, more than half of the trader household respondents still wanted to keep the business while over 25% planned to expand it in the future (Appendix B, Table 3.67). Besides the above-mentioned advantages and opportunities of the fish trade, more than half of the household respondents did not plan to change (reduce or expand) the business because they had experience as well as skill in fish trade, and trading fish was regarded as the primary occupation by some respondents. They did not have other jobs to do or enough time to spend on the fish trade. Additionally, some traders wanted to expand the business, but could not due to some constraints, including: limited capital, not enough volume of fish and processed fish demanded, and little change of fish price (wild) in markets. Furthermore, one-quarter of the respondents planned to expand the business in order to get more profit and improve their living conditions.

Fish Exporters

Fish export was one of many careers. While some fish exporter household respondents considered fish export the main occupation in their families, some respondents regarded it as additional or secondary occupation in their families. However, no matter whether it was the main or additional job, it was considered an easy job which brought about profit and household income to support the family. In contrast, nearly all of the household respondents (80%) planned to reduce the business because of the scarcity of fish, making its price increase (Appendix B, Table 3.68). It was difficult to sell the processed products and pay for informal fees. Moreover, sometimes they made a loss that made them felt tired with the business.

Fish Processors

Fish processing was considered by fish processors as an easy business because they had skills in this business. Besides spending low capital investment, fish processed products were easy to be sold since processors had a lot of permanent consumers. As reported, volume of small-sized fish was abundant for processing and it was such a great opportunity that fish processors who were living near fish supplying sources where they did not have to spend much cost on transportation and informal fee payment, and could avoid much weight loss of fish and fish degradation before being processed. Moreover, they could make use of and augment value of small-sized fish left over from markets, regarded as waste fish in some areas, through value added products. In addition, for fish processors, processing fish helped them gain additional income, which could improve their living condition. More than this, via fish processing they could help society reduce poverty by providing jobs to the poor. As far as fish processors were concerned, development trends of the freshwater small-sized fish processing industry in the coming time was supposed to increase by 54.5% of fish processor household respondents (Appendix B, Table 3.69). This was due to the fact that fresh freshwater small-sized fish, used as raw materials for fish processing, was abundant, and processed products of small-sized fish were easier to sell than that of big-sized fish. And, fish processors spent less capital on processing small-sized fish. When asked about future changes in the processing of freshwater small-sized fish, 63.7% of the household respondents planed to change the business, of which 36.4% planed to reduce while 27.3% planed to expand the business (Appendix B, Table 3.70). Most of them wanted to reduce the business because they lacked capital (for middle-scale processors) to buy raw materials as well as modern machines (for beheading fish and pumping fish up into the house) to process more small-sized fish and with good quality. Moreover, there was also lack of labor to do the work. The number of buyers, if not decreased, at least remained the same. Fish processing was thought of as a tiring job. Sometimes fish processors got lost in the business when price of fish and processed fish was changed unexpectedly. Therefore, some of processors wanted to find a new job. Nevertheless, 36.4% of the household respondents planed to have no change in the business due to the fact that they own processing equipment and a suitable place for stocking the processed products. Moreover, because numbers of buyers remained the same, and numbers of labor and capital was low, it was expected that the business was only maintained, not expanded.

End Consumers

In the future, there would be no change in consumption of fresh and processed freshwater small-sized fish by nearly 70% of fish consumer households (Appendix B, Table 3.71). This was because fresh and processed freshwater small-sized fish was affordable (having low price) and was an important source of animal protein. Moreover, it was easy to buy since it was always available everywhere. Furthermore, fresh small-sized fish could be used to process into many types of products including fish paste and fermented fish, etc.

Challenges/Constraints

There were many problems faced by the chain actors in operating their business. The chain actors described those problems as follows:

Fishermen

For most of fisher households, fishing was their only job since they were living along or on the river. There were a lack of alternative livelihood activities and opportunities to find additional income to support their families. Moreover, they lacked labor that could help them during fishing. They could not depend on fishing while the volume of fish caught was not regular. After they caught fish, they had difficulty selling it since its price competed with cultured fish imported from neighboring countries. Furthermore, as reported, the number of fishermen was increasing at the same time that fishing grounds became narrow, lessening the normal area of fishing grounds that each fisher used to fish, and decreasing the volume of fish catch per fishing effort. Cases of unofficially being asked for money by local authorities were common. Additionally, the globally increasing price of goods, especially gasoline, and natural phenomena such as storms and heavy rains also affected and threatened their fishing activities.

Fish Farmers

Some fish fingerlings used by fish farmers were caught from nature and were difficult to find, making its price high. Therefore, increase in price of fingerling was one of many problems for fish farmers. Another problem, there was shortage of freshwater small-sized fish for fish feed, particularly during closed season. Demand on using the small-sized fish for fish feed was increasing, so fish farmers had to compete with each other to get the small-sized fish. In addition, the small-sized fish was scarce, which resulted in an increase in its price. Furthermore, consumption demand for domestic cultured fish declined and its price also decreased and became unstable because domestic cultured fish competed with lower-priced imported cultured fish mainly from Vietnam and Thailand. Consequently, fish farmers faced difficulties selling their fish. Also, it was a little bit difficult for them to do permission letter for fish culture and stocking license. Besides this, they lacked capital to standby and expand their business. Usually, there was disturbance from competent local authorities who came to ask for money. Normally, increasing price of equipment and other raw materials used in fish farming would more or less affect fish farmers.

Fish Traders

Availability of freshwater small-sized fish for selling was the only important thing for fish traders. Therefore, having no or not enough small-sized fish for selling was their big problem. Fish traders had to spend much time traveling and waiting, and compete with other fish traders to buy fish for selling. In some cases, they had to provide loan in advance to fish suppliers like fishers and fish collectors to get the fish. Moreover, consumption demand on the small-sized fish was made known decreased compared to big-sized fish. Besides competing with the domestic big-sized fish, it was also challenged by imported cultured fish, which made its price lower and changed irregularly. Hence, fish traders had difficulties selling and sometimes they could get low profit or even sell at a loss. Furthermore, some formal-fee payments like administrative costs, annual taxes, seasonal taxes and payments on security, environment and utilities, and informal-fee payments affected the business of fish trade, to some extent.

Fish Exporters

Fish exporters were also confronted with some of the same problems that fish traders experienced. In addition to the above problems, fish exporters met some more difficulties related to the instability of freshwater small-sized fish supply and demand. Reportedly, market demand on the small-sized fish from Thailand was decreased because they could culture the fish by themselves in their country. And, the price of the small-sized fish exported was set by buyers. This meant that although fish exporters had fish for selling, they were not the ones who determined the price of their products. Even more, in some circumstances, their products were sold on credit. Regarding conservative techniques to maintain quality of the products and reduce so much weight loss during exporting, it was still limited. Additionally, every year fish exporters had much expense due to labor costs and taxes on income.

Fish Processors

Volume of freshwater small-sized fish was usually not stable. It was regularly available only a few months in open season. Because of this, some fish processors encountered no or not adequate small-sized fish for processing for most of the time. Furthermore, price of the small-sized fish was not stable, so price of the processed small-sized fish also changed. Additionally, consumption demand as well as selling volume of the processed products declined due to the fact that some consumers could process the fish into their preferable preserved products by themselves. Moreover, fish processors were lack of processing techniques and modern processing machines, such as fish beheading machines, etc. More importantly, there was competition for the products from different fish processors in markets and there was no market support on the products. Also, informal-fee payment during processing and transporting was high and thus affected fish processors.

Major Suggestions for Upgrading the Value Chain of Freshwater Small-sized Fish

In order to upgrade the value chain as well as to improve marketing and management solutions of freshwater small-sized fish in the LMB of Cambodia, some major suggestions/recommendations are proposed as follows:

Training in fisheries law should be done to make sure that all fishermen clearly understand what is in the law in order to know their privileges and how to obtain the right to fish to avoid being cheated by any illegal officials. Moreover, there should also be enforcement of the fisheries law, especially of fishing activities to eliminate illegal and over-fishing that led to the depletion of fisheries resources, and fish trade and export.

The government should limit imported volume of cultured fish into Cambodia that would compete with wild fish and domestic cultured fish in terms of price. The government should strictly determine and set out a clear regulation on when there should be import and export of fish into and out of the country in order to have a balance between supply and demand on fish within the country. To do so, quality of products should be controlled and ensured to build the trust of consumers.

The procedure for obtaining licenses for fish culture, stocking, loading, trading and export should be simplified and sped up.

Techniques for fish hatcheries and producing pelleted fish feed by using locally available natural resources without using small-sized fish should be introduced to fish farmers.

There should be support from the government by providing price information of fresh and processed products of fish (cultured and wild) in markets, intervening price of the products, and finding more market opportunities of the products (export markets).

Fish processors should form associations to ensure that their products are sold at the same price and to avoid market competition. The government should also support them through policy-making, providing processing techniques/skills for good quality processing, and establishing quality control institution to standardize the processed products that would broaden both domestic and export market opportunities for the processed products.

Products should be processed into final products before being exported so that more value can be added, and more job opportunities can be created for Cambodian people, so as to reduce migration for work to other places or other countries.

Establishment of micro-credits or financial organizations providing loans with low interest rates should be more encouraged and motivated.

Law enforcement should be strengthened by eliminating unimportant or informal-fee payment during business transactions along the chain. Furthermore, all formal-fee payments determined by the law should be taken or charged at a reasonable amount of money (e.g. 5% of income for exporters).

More livelihood activities and vocational skills should be created and provided to all people as well as the chain actors, especially to fishers in order to reduce fishing pressure and earn additional income to better their living conditions.

Summary and Conclusion

Summary

Freshwater small-sized fish is considered a crucial and irreplaceable foodstuff (source of animal protein) for Cambodian people, especially for the poor. More than ensuring food security for the nation, freshwater small-sized fish provides job opportunities and household income to millions of people through fishing, fish farming, trading, processing and exporting activities. The study on the Value Chain Analysis of Freshwater Small-Sized Fish in the Lower Mekong Basin (LMB) of Cambodia was conducted with three main objectives: 1) to describe and analyze the situation of stakeholders participating in value chain of freshwater small-sized fish; 2) to analyze the value chain; and 3) to propose improvements for upgrading the value chain for improved marketing and management solutions.

The study was undertaken in four provinces, namely Kandal, Kampong Chhnang, Battambang and Siem Reap provinces, and Phnom Penh city. Stakeholders relevant to the value chain of freshwater small-sized fish were categorized into 6 different groups: fishermen, fish farmers, traders, exporters, processors and end consumers. In total, 206 samples were purposively selected and interviewed by using 6 different types of questionnaires. Key informant persons (KIP), such as officers of municipal and provincial fisheries administration cantonment and local authorities, in each selected study area were also interviewed. Not only primary data received through interviewing with targeted samples and KIP but also secondary data derived from various sources like government and NGOs was needed in this study. The primary data, once completed, checked and cleaned, was installed and analyzed in MS Access.

Fishermen were the only supply sources of freshwater small-sized fish. Normally, the value chain of small-sized fish mostly exists in the open season, especially during peak period from November to February when the small-sized fish are abundant. However, the months might vary across the provinces. Because 70% of fisher households went fishing for household consumption and sale, about 90% of the fish caught was for sale and only 10% was kept for own consumption. Around 24,753 kg of the small-sized fish were caught per household in the last open season (2011-2012), in which 23,233 kg were caught in the peak period and 2,124 kg were caught in the low period of open season. Moreover, 300 kg of the small-sized fish were caught in last closed season (2011-2012). Totally, at least 24,918 kg of the small-sized fish were caught per household last year, and 49 fish species (including juveniles of commercially important and big-sized fish species). The price of the small-sized fish varied by species and season but ranged from USD 0.1 to 1.3 per kg. At least 17 species of fish were found being cultured in either ponds or cages. The types of fish feed used for fish culture included freshwater small-sized fish (both fresh and dried forms), marine small-sized fish, commercial/ pellet feed, rice bran and other additional feeds. Nearly half of fish farmers (45%) use freshwater small-sized fish as fish feed. On average, volume of feed used for fish culture was 54,686.4 kg per crop per household, most of which was freshwater small-sized fish (31%). The use of freshwater small-sized fish as fish feed was reported increased (40% of fish farmer households), particularly last year (2011-2012) because of the abundance of freshwater small-sized fish. Probably 38 fish species of freshwater small-sized fish were traded. On average, the traded volume of fresh freshwater small-sized fish was 1,922 kg per day per household (2,001 kg per day in open season and 57 kg per day in closed season). Fresh small-sized fish was priced from USD 0.2 to 1 per kg. Moreover, the average volume of processed small-sized fish sold was 56.2 kg per day (57 kg during open season and 27 kg during closed season). Types of processed freshwater small-sized fish traded included salted-dried fish (USD 0.8/kg), smoked fish (USD 4./4kg, or 0.33/skewer), fermented fish (USD 1./kg), and fish paste (USD 1.1/kg). Export of freshwater small-sized fish was done in both fresh and processed forms. 10 species of freshwater small-sized fish were exported. Average exported volume of freshwater small-sized fish was 1,527 kg per day (1,556 kg/day during open season, and 50 kg/day during closed season). By excluding juveniles of big-sized fish species, price of fresh

freshwater small-sized fish ranged from USD 0.23 to 1.75 per kg. Processed freshwater small-sized fish exported included salted fish and fish paste. The average exported volume of processed small-sized fish was 14,792 kg per day (15,000 kg/day in open season and 4,000 kg/day in closed season). Price of salted fish was USD 0.45 per kg and fish paste was USD 0.55 per kg. There were five types of processed freshwater small-sized fish produced by processors including: salted-dried fish, smoked fish, fish sauce, fermented fish and fish paste. On average, volume of processed freshwater small-sized fish produced was 210,957 kg per year and sold out 5,158 kg per time. The price of the processed products was very similar for salted-dried fish, fermented fish and fish paste, which was USD 1 per kg, except smoked fish USD 0.3 per skewer and fish sauce USD 0.5 per liter. Freshwater small-sized fish was bought every 3.8 days (for fresh fish) to 104 days (for fish paste) per time. An average buying volume of the products was 0.7 kg per time for fresh and salted-dried fish (USD 0.9/kg), 3.1 skewers per time for smoked fish (USD 0.3/skewer), 5.7 kg per time for fermented fish (USD 1.6/kg), and 7.6 kg per time for fish paste (USD 1.7/kg).

For the marketing channels of freshwater small-sized fish, fish collectors/middlemen/wholesalers absorbed 41.5% of the total volume of the small-sized fish supplied by fishermen. Processors handled 30.5% of the fish in the chain before processing and supplying to various chain actors. Just less than 20% of the fish was sold directly by fishers to end consumers in retailed markets. Besides being kept for household consumption, the rest of the small-sized fish was sold as feed to fish/animal/crocodile farmers (14%) and Vietnamese processors living in the areas (1.6%) by fisher households. Only 0.6% of the fish was exported to Thailand by fish exporters/exporting companies in both fresh and processed forms (semi-final processed products).

Some suggestions/recommendations were proposed in order to upgrade the value chain of freshwater small-sized fish. Clear regulations on the appropriate time the fish should be imported and exported into and out of the country should be strictly determined and set out in order to balance between supply and demand on fish within the country. Procedure of obtaining licenses for fish culture, stocking, loading, trade and export should be simplified and sped up. Techniques for fish hatcheries and producing pellets or fish feed by using locally available natural resources without using small-sized fish should be introduced and given to fish farmers. There should be support from the government by providing price information of fresh and processed products of fish (cultured and wild) in markets, intervening price of the products, and finding more market opportunities of the products (export markets). Processed products should be processed into final products before being exported so that more value can be added, and more job opportunities can be created. Establishment of micro-credit or financial organizations providing loans with low interest rates should be encouraged and motivated. Furthermore, there law enforcement should be strengthened by eliminating unimportant or informal fee payments during business transactions along the chain.

Conclusion

There were seven main groups of actors engaged in the value chain of freshwater small-sized fish in the LMB of Cambodia: fishers, fish farmers, fish collectors/middlemen, wholesalers, processors, exporters and retailers. Many business transactions took place through several marketing channels with different combinations of chain actors before freshwater small-sized fish (fresh and processed forms) could reach end consumers. Fishermen were the only supplying source of freshwater small-sized fish to various groups of actors in the chain, of whom, fish collectors/middlemen/wholesalers played a vital role in delivering the largest volume of the small-sized fish to other chain actors. Most of the small-sized fish were traded in the country and only a small proportion was exported to Vietnam and Thailand in both fresh and processed forms (semi-final processed products). Nearly three-quarters of the small-sized fish were marketed for domestic human consumption. Compared to before 2011, volume of the small-sized fish caught and traded had remarkably increased in 2011 - 2012. Nevertheless, this increase brought difficulties to some traders in selling their fish because the price was accordingly decreased.

It is true that freshwater small-sized fish are a household income source for the families not just for fishers alone but for all chain actors including fish collectors/middlemen, wholesalers, retailers, exporters and processors, and other relevant stakeholders who directly and indirectly benefited from the business. However, the study found that these actors were highly dependent on the small-sized fish, which always varied by season and were abundant only in a short period. Therefore, they would be more vulnerable if they relied solely on the small-sized fish. By taking into account some difficulties encompassing the lack of capital and labor forces, this condition had limited plans for business expansion of most chain actors. Additionally, although freshwater small-sized fish was abundant in a few days during peak period of open season, there was tradeoff between the trade and use of freshwater small-sized fish for human consumption and for fish/animal/crocodile feed due to the fact that more than one-quarter of the small-sized fish traded in domestic markets were used as feed for fish, animals and crocodile culture. Since the study showed that the use of the small-sized fish as feed increased compared to the past few years, this might influence and affect volume and availability of the small-sized fish traded for human consumption that might also have bad impact on small-scale fish traders in the chain.
Supposing that freshwater small-sized fish used for fish culture was more profitable than that used for human consumption, it was not a sustainable way of development. Therefore, using freshwater small-sized fish for human consumption would be a better choice for the sustainable use of freshwater small-sized fish which could ensure food security, sustainable job opportunities, and income of chain actors and related stakeholders.

To sustain and develop the value chain of the small-sized fish in the LMB of Cambodia, appropriate plans and measures should be carefully and considerably made and implemented with collaboration of all chain actors, local communities and authorities, government, NGOs and other functional organizations on strictly determining a clear regulation on allowance of import and export of fish into and out of the country to balance between supply and demand on fish in the country. There should also be support from the government by providing price information of fresh and processed fish (cultured and wild fish) in markets, intervening fish price, and finding more market opportunities of the products (external markets). Processed products should be processed into the final one before exported so that more value could be added, and more job opportunities could be generated. Establishment of financial organizations with low interest rates should be encouraged and motivated. Law enforcement should be strengthened by eliminating unimportant/informal-fee payment during business transaction along the chain.

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APPENDIX A

LIST OF FIGURES

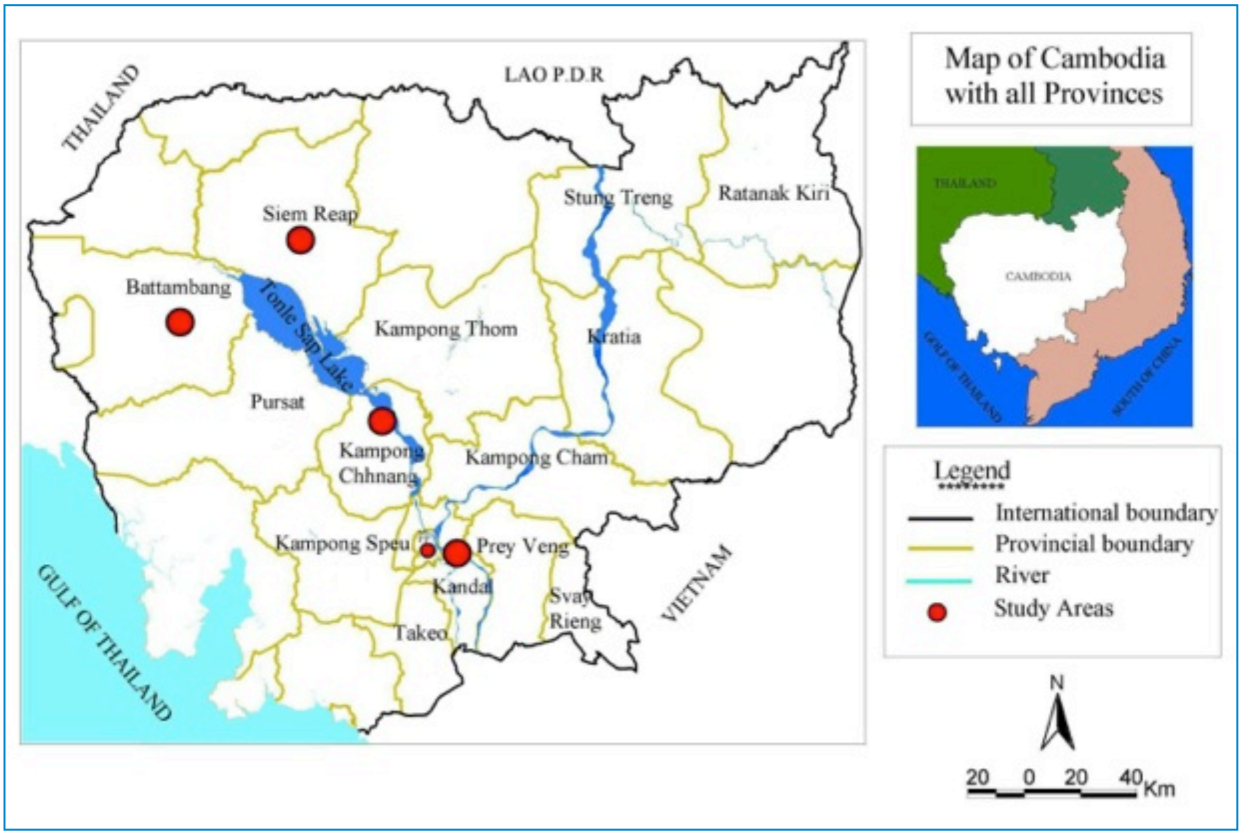

Figure 2.1: *Map of Cambodia showing the study areas in the selected provinces and city.*

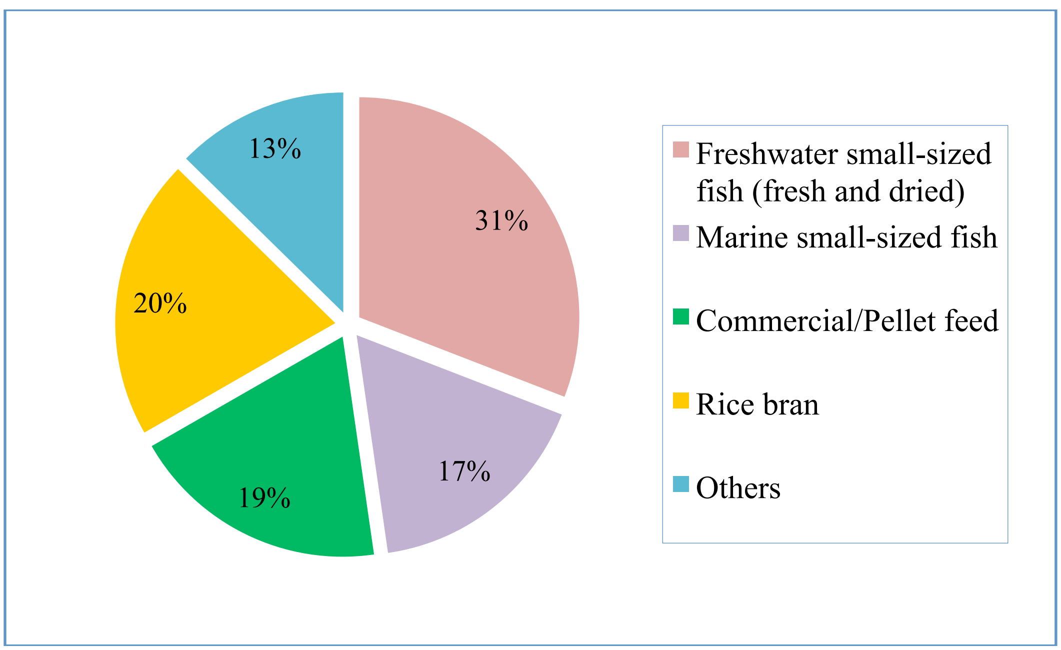

Figure 3.1: *Percentage of types of feed used for fish culture.*

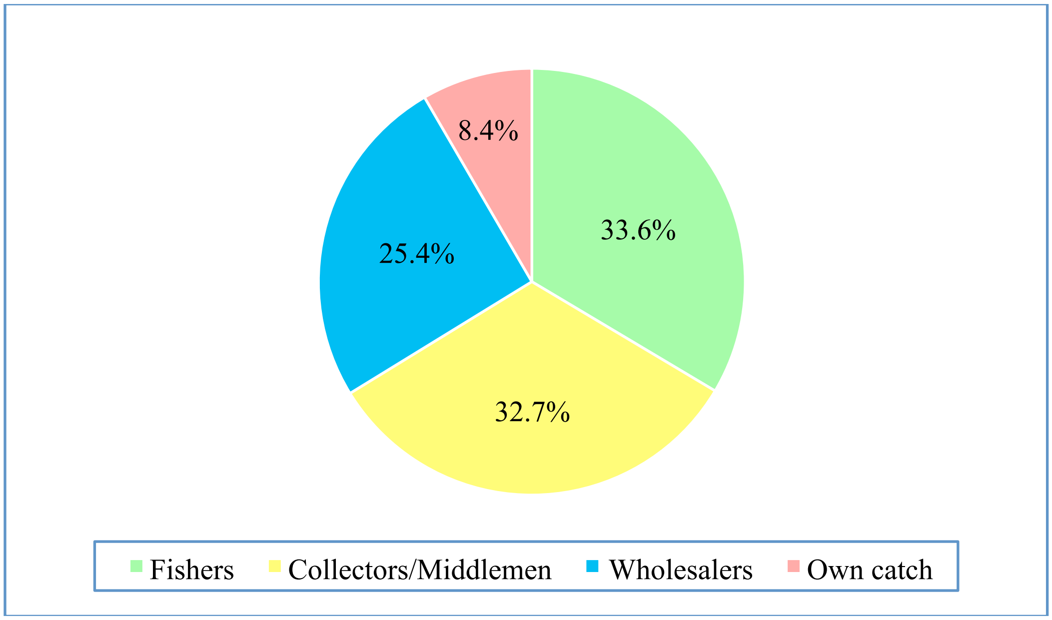

Figure 3.2: *Percentage of supplying sources of fresh freshwater small-sized fish (% of volume) (fish traders).*

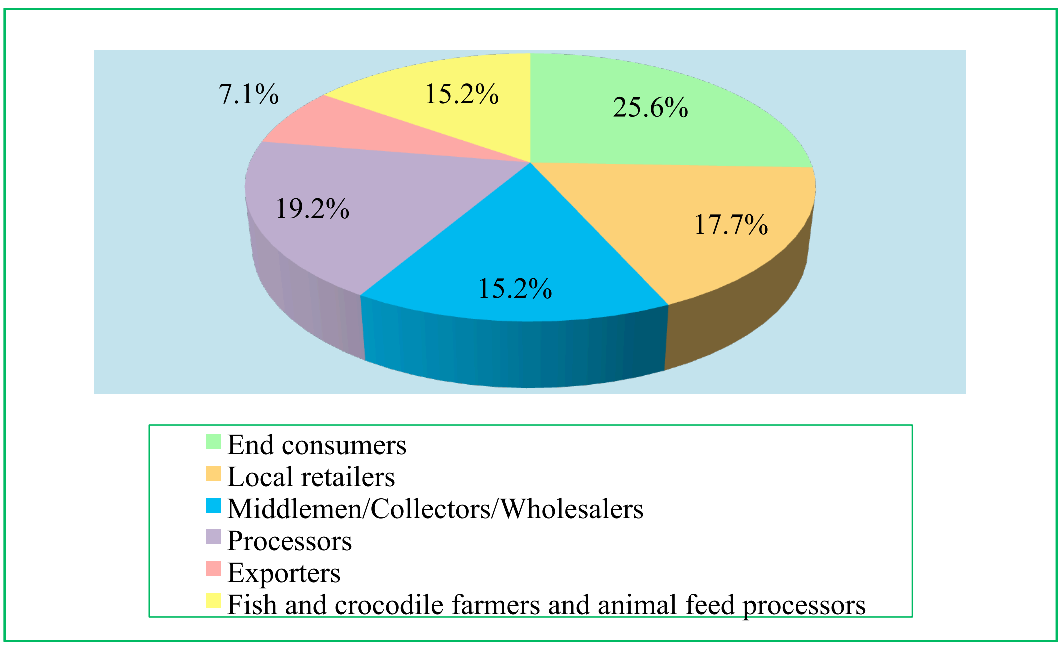

Figure 3.3*: Percentage of demanding sources of fresh freshwater small-sized fish (% of volume) (fish traders).*

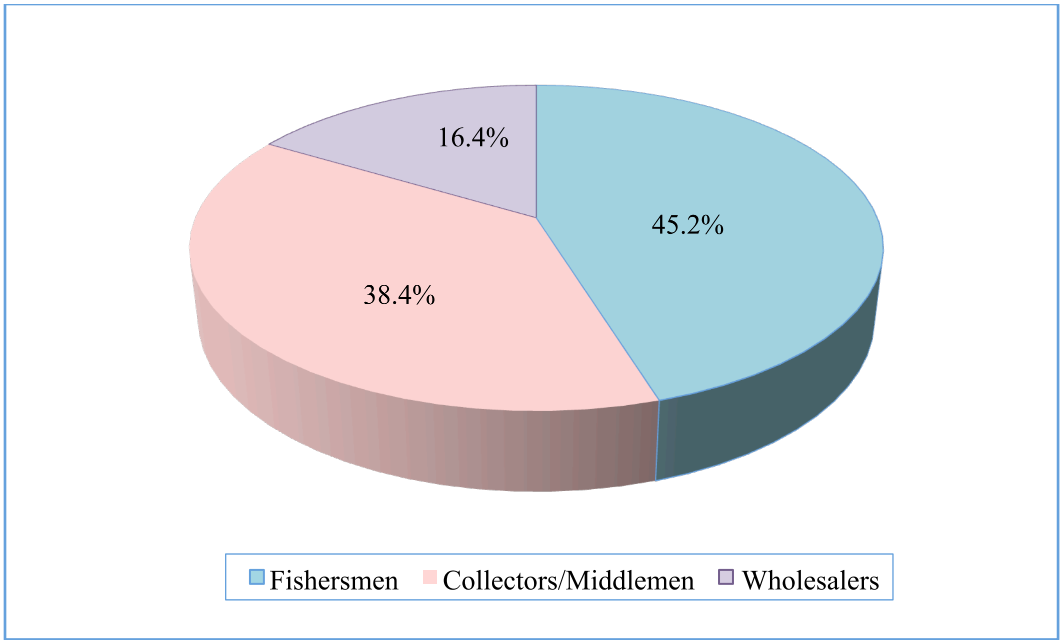

Figure 3.4: *Percentage of supplying sources of fresh freshwater small-sized fish for processing (% of quantity) (fish traders).*

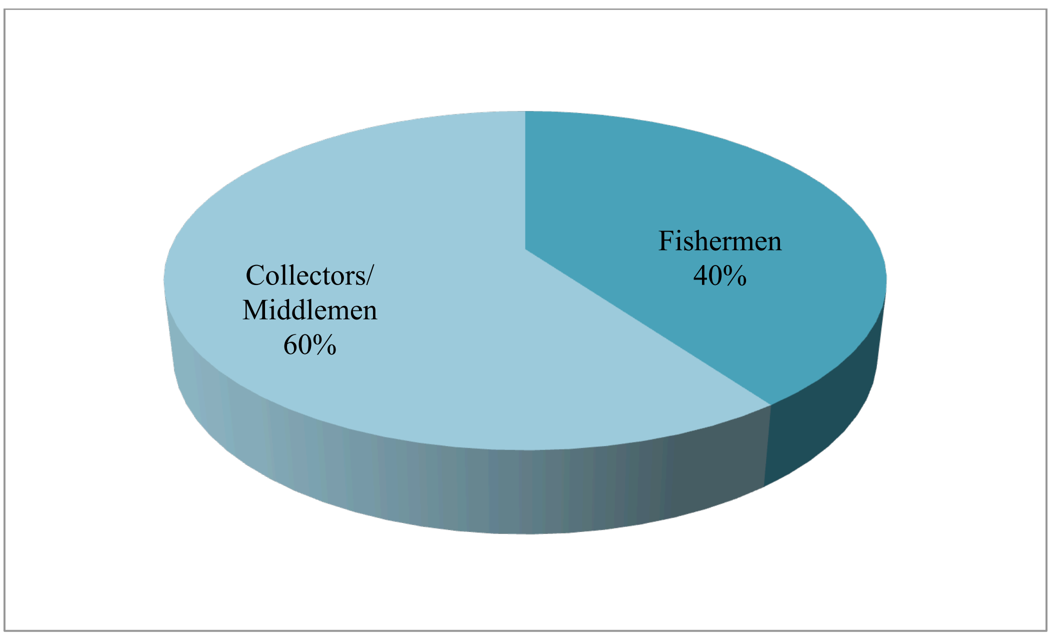

Figure 3.5: *Percentage distribution of supplying sources of fresh freshwater small-sized fish (% of volume) (fish exporters).*

APPENDIX B

LIST OF TABLES

Table 2.1: *Number of sample households by stakeholder and province/city.*

Province/City Stakeholders	Phnom Penh	Kandal	Kampong Chhnang	Battam Bang	Siem Reap	Total
1. Fishermen	10	10	10	10	10	50
2. Fish Farmers	13	17	10	-	-	40
3. Traders	10	16	11	6	7	50
4. Exporters	1	-	1	1	2	5
5. Processors	2	2	3	3	1	11
6. End Consumers	10	10	10	10	10	50
Total	**46**	**55**	**45**	**30**	**30**	**206**

I. General Situation and Livelihood Activities of Chain Actors in the Value Chain

1.1 Fishermen

Table 3.1: *Age group distribution of respondent households by sex in all provinces.*

Age group (years)	Male		Female		Both	
	No.	(%)	No.	(%)	No.	(%)
20 - 30	5	10	4	8	9	18
31 - 40	9	18	3	6	12	24
41 - 50	12	24	3	6	15	30
51 - 60	8	16	3	6	11	22
61 and above	3	6	-	-	3	6
Total	37	74	13	26	50	100

Table 3.2*: Average years of experiences in fishing by sex and type of fishing activities.*

	Male (n=37)			Female (n=13)			Both (n=50)		
Type of fishing	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Small scale	25.4	2	50	19.2	2	33	23.8	2	50
Large scale/Bag Net (Dai)	16.5	14	19	-	-	-	16.5	14	19
All	24.9	2	50	19.2	2	33	23.5	2	50

Table 3.3: *Seasonality of fishing per year by type of fishing activities in all provinces.*

Description	Small scale		Large scale/Bag net		All	
	No.	(%)	No.	(%)	No.	(%)
Open season	13	26	2	4	15	30
Whole year	34	68	-	-	34	68
Occasionally	1	2	-	-	1	2
Total	48	96	2	4	50	100

Table 3.4: *Name of months fishers frequently go fishing for freshwater small-sized fish by season in all provinces.*

Name of months	Open Season								Closed Season			
	General Fish Species				FSSF* Species				General Fish Species		FSSF* Species	
	Peak Period		Low Period		Peak Period		Low Period					
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
January	43	25.4	8	3.5	38	29.9	8	4.3	-	-	-	-
February	32	18.9	18	8.0	25	19.7	16	8.7	-	-	-	-
March	16	9.5	33	14.6	11	8.7	30	16.3	-	-	-	-
April	7	4.1	41	18.1	4	3.1	30	16.3	-	-	-	-
May	-	-	48	21.2	-	-	34	18.5	-	-	-	-
June	-	-	-	-	-	-	-	-	34	24.8	28	24.1
July	-	-	-	-	-	-	-	-	34	24.8	30	25.9
August	-	-	-	-	-	-	-	-	34	24.8	29	25.0
September	-	-	-	-	-	-	-	-	35	25.5	29	25.0
October	10	5.9	40	17.7	4	3.1	29	15.8	-	-	-	-
November	28	16.6	21	9.3	18	14.2	20	10.9	-	-	-	-
December	33	19.5	17	7.5	27	21.3	17	9.2	-	-	-	-
Total	169	100.0	226	100.0	127	100.0	184	100.0	137	100.0	116	100.0

Note: * FSSF= Freshwater Small-sized Fish

Table 3.5: *Types of fishing grounds where fishers access to by season in all provinces.*

Fishing grounds	Open season		Closed season		Both	
	No.	(%)	No.	(%)	No.	(%)
Great Lake	15	23.4	8	20.5	23	22.3
Tonle Sap River	32	50.0	19	48.7	51	49.5
Mekong River	5	7.8	-	-	5	4.9
Bassac River	2	3.1	-	-	2	1.9
Small rivers/lakes (connected to Tonle Sap, Bassac and Mekong rivers)	3	4.7	3	7.7	6	5.8
Inundated forests	5	7.8	7	17.9	12	11.7
Canals	2	3.1	2	5.1	4	3.9
Total	64	100.0	39	100.0	103	100.0

Table 3.6: *Detailed information on fishing activities by season in all provinces.*

Description	Open Season						Closed season		
	Peak Period			Low Period					
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
No. of months in fishing activities (month)	3.3	2	7	4.5	1.0	6	3.9	1.0	4.0
No. of days in fishing activities (day)	22.2	6	30	20.9	3.0	30	18.3	4.0	30.0
Amount of fish (general species) caught per day (kg/day)	656.1	8	15,000	190.2	3.0	7,500	6.4	0.6	20.0
Percentage of FSSF (%)	77.5	5	100	53.6	-	100	68.7	15.0	100.0
Income from fishing activities per day (USD/day)	164.4	2	5,000	38.8	0.8	875	5.9	0.8	16.6
Percentage of income from FSSF (%)	66.6	2	100	43.2	-	100	61.0	7.7	100.0
Other income excluding fishing (USD/day)	9.9	-	250	10.4	-	250	8.1	-	100.0
Total income per day (USD/day)	174.4	2	5,250	49.2	0.8	1,125	12.4	0.8	100.0

Note: * Exchange rate: USD 1 = 4,000 Riel

Table 3.7: Species, quantity and price of FSSF caught per day in the last seasons (2011-2012).

Fish species		Open season				Closed season		All	
		Peak Period		Low Period					
Scientific Name	Khmer	Qty.	Price	Qty.	Price	Qty.	Price	Qty.	Price
1. *Labiobarbus spp.*	Ach Kok	52.6	0.2	1.9	0.5	0.6	0.6	35.0	0.3
2. *Puntius orphoides*	Ampil Tum	3.0	0.2	-	-	-	-	3.0	0.2
3. *Cynoglossus feldmanni*	Andat Chhke*	4.0	1.5	1.6	1.8	-	-	2.3	1.5
4. *Clarias spp.*	Andeng*	3.8	0.5	1.4	0.7	0.2	0.5	2.6	0.7
5. *Puntius rhombeus*	Angkat Prak Bandoul	4.4	0.4	2.0	0.8	0.5	0.4	3.0	0.5
6. *Clupeichthys spp.*	Ampov	3.0	1.0	25.1	0.8	-	-	25.8	0.8
7. *Opsarius koratensis*	Changva	5.4	0.4	1.2	0.8	0.8	1.3	1.8	0.8
8. *Rasbora spp.*	Changva Moul	72.0	0.8	9.0	0.9	1.5	0.6	27.9	0.8
9. *Albulichthys albuloides*	Chhkok Tituy*	0.3	0.3	-	-	0.3	0.5	0.3	0.4
10. *Cyclocheilichthys spp.*	Chhkok*	11.7	0.5	6.4	0.6	1.9	0.8	7.9	0.6
11. *Hemibagrus spp.*	Chhlaing*	9.8	0.8	3.7	1.2	0.5	0.8	5.2	0.9
12. *Macrognathus spp.*	Chhlonh*	0.5	0.4	0.3	0.8	600.2	0.4	0.4	0.5
13. *Hypsibarbus spp.*	Chhpin*	4.5	0.2	2.2	0.5	0.5	0.7	2.6	0.5
14. *Pteropangasius pleurotaenia*	Chhveat	27.8	0.6	1.7	0.6	1.3	1.0	21.4	0.7
15. *Coilia spp.*	Chonlourn Moan	20.1	0.3	6.0	0.3	1.0	0.6	5.6	0.4
16. *Puntioplites spp.*	Chrorkeng*	12.7	0.5	3.7	0.8	1.4	1.0	7.6	0.7
17. *Parachela spp.*	Chunteas Phlouk	5.2	0.3	3.6	0.7	2.9	0.7	3.6	0.5
18. *Barbodes spp.*	Ka Hae*	-	-	0.5	0.8	0.5	0.8	0.5	0.8
19. *Catlocarpio siamensis*	Ka Hour/Kul Raeng*	2.0	0.5	-	-	-	-	2.0	0.5
20. *Labeo chrysophekadion*	Kaek*	9.3	0.2	1.0	0.6	0.3	0.6	6.3	0.4
21. *Parambassis spp.*	Kanchanh Chrass	17.6	0.1	13.4	0.3	1.5	0.4	8.3	0.3
22. *Mystus spp.*	Kanhchos	11.2	0.6	6.8	0.9	1.4	1.0	6.2	0.8
23. *Yasuhikotakia spp.*	Kanhchrouk	25.3	0.6	7.6	0.7	0.3	1.3	23.2	0.7
24. *Parambassi wolffi*	Kantrong Preng	1.2	0.1	-	-	0.3	0.3	0.8	0.2
25. *Pristolepis fasciata*	Kantrorb*	0.8	0.3	5.2	0.3	0.8	0.3	3.7	0.3
26. *Arius spp.*	Ka'ork	-	-	1.0	1.0	-	-	1.0	1.0
27. *Pangasius conchophilus*	Kae/Pra Kae*	-	-	2.0	1.0	-	-	2.0	1.0
28. *Polynemus multifilis*	Kom Pream	4.3	0.8	2.8	1.2	0.1	0.9	3.7	0.9
29. *Amblyrhynchichthys truncatus*	Kombot Chrormors	3.5	0.2	13.7	0.7	0.1	0.8	14.0	0.7

Fish species		Open season				Closed season		All	
		Peak Period		Low Period					
Scientific Name	Khmer	Qty.	Price	Qty.	Price	Qty.	Price	Qty.	Price
30. *Trichogaster spp*	Kompleanh	4.7	0.3	1.6	0.5	1.0	0.5	2.6	0.5
31. *Kryptopterus moorei*	Kompleav	-	-	1.0	1.0	-	-	1.0	1.0
32. *Cirrhinus microlepis*	Kralang/Prourl*	72.4	0.3	1.1	0.4	-	-	70.9	0.4
33. *Anabas testudineus*	Kranh	1.1	0.6	0.3	0.8	1.0	0.7	0.9	0.7
34. *Cosmochilus harmandi*	Krapol Bay/ Chhkok Kdar*	6.0	0.9	-	-	-	-	6.0	0.9
35. *Wallago attu*	Krapot/Sanday*	0.3	0.2	-	-	-	-	0.3	0.2
36. *Ompok bimaculatus*	Kromorm*	7.5	0.9	1.0	1.3	-	-	5.3	1.1
37. *Osteochilus lini*	Kros	15.3	0.3	2.7	0.4	1.0	0.6	8.4	0.4
38. *Dangila spp.*	Khnorng Veng	274.0	0.3	33.3	0.5	1.1	0.6	131.2	0.3
39. *Thynnichthys thynnoides*	Linh	19.5	0.3	6.3	0.5	0.6	0.5	17.5	0.4
40. *Hyporhamphus limbatus*	Phtoung	1.4	1.2	0.5	1.9	-	-	1.0	1.3
41. *Pangasius larnaudiei*	Pou*	10.0	0.7	1.5	0.9	-	-	6.7	0.9
42. *Boesemania microlepis*	Promah*	3.4	0.3	1.0	0.2	-	-	2.2	0.2
43. *Acantopsis spp.*	Reus Chek*	918.0	1.0	10.0	1.3	-	-	464.0	1.1
44. *Henicorhynchus lobatus*	Riel Angkam	415.1	0.2	148.5	0.5	1.0	0.7	267.9	0.4
45. *Henicorhynchus siamensis*	Riel Tom	5.0	0.4	-	-	-	-	5.0	0.4
46. *Notopterus notopterus*	Slat*	8.0	0.5	0.5	1.1	-	-	4.3	0.8
47. *Paralaubuca riveroi*	Sleuk Reussey	297.0	0.2	400.7	0.6	-	-	335.8	0.3
48. *Cyclocheilichthys spp.*	Sraka Kdarm	3.1	0.3	0.5	0.5	0.4	0.9	3.0	0.4
Total		586.7	0.4	177.1	0.7	4.5	0.8	365.8	0.6

Note: * Juvenile of commercially important fish species
Exchange rate: USD 1 = 4,000 Riel

Table 3.8: *Average quantity of fish catch per year during last year (2011-2012).*

Fish species	Open season (kg/season)			Closed season (kg/season)	Total (kg/year)
	Peak period	Low period	Total		
All fish species (big &small-sized fish)	27,732.1	4,063.9	31,230.0	490.6	31,550.4
Small-sized fish	23,232.7	2,124.1	24,752.7	300.2	24,918.1

Table 3.9: *Top 10 species of freshwater small-sized fish by percentage of frequency of catch in all provinces during last year (2011-2012).*

N°	Open season				Closed season		All	
	Species	Peak Period (%) (n=50)	Species	Low Period (%) (n=50)	Species	(%) (n=50)	Species	(%) (n=50)
1	Riel	10.2	Riel	8.5	Riel	3.9	Riel	22.6
2	Chrorkeng*	6.6	Chrorkeng*	6.3	Chrorkeng*	3.2	Chhrorkeng*	16.1
3	Kanhchos	4.6	Kanhchos	4.6	Kanhchos	2.9	Kanhchos	12.2
4	Kros	4.4	Kros	4.1	Kros	2.9	Kros	11.4
5	Kanhchrouk	4.4	Chhkok*	3.4	Komphleanh	1.9	Kanhchrouk	9.7
6	Khnorng Veng	2.7	Khnorng Veng	2.7	Chhkok*	1.0	Chhkok*	6.3
7	Kaek*	2.9	Komphleanh	2.4	Chhveat	0.7	Khnorng Veng	6.1
8	Chhkok*	2.7	Chhveat	1.9	Kranh	0.7	Chhveat	5.4
9	Chhveat	2.9	Kaek*	1.7	Chunlournh Moan	0.7	Kaek*	5.4
10	Komphleanh	2.4	Kam Pream	1.7	Chhlonh*	0.7	Komphleanh	4.9
	Total	43.8		37.5		18.7		100.0

Note: * Juvenile of commercially important fish species

Table 3.10: *Top 10 species of freshwater small-sized fish by volume caught per day in all provinces during last year (2011-2012).*

N°	By volume			By price		
	Species	Total catch (kg/day)	Price (USD/kg)	Species	Total catch (kg/day)	Price (USD/kg)
1	Reus Chek*	464.0	1.1	Andat Chhke*	2.3	1.5
2	SleukReussey	335.8	0.3	Phtoung	1.0	1.3
3	Riel	267.9	0.4	Reus Chek*	464.0	1.1
4	KhnorngVeng	131.2	0.3	Kromorm*	5.3	1.1
5	Kralang*	70.9	0.4	Kae/PraKae*	2.0	1.0
6	Ach Kok	35.0	0.3	KomPhleav	1.0	1.0
7	ChangvaMoul	28.1	0.9	Kaork	1.0	1.0
8	BandolAmpov	25.8	0.8	Pream	3.7	0.9
9	Kanhchrouk	23.2	0.7	Pou*	6.7	0.9
10	Chhveat	21.4	0.7	Chhlaing*	5.2	0.9

Note: * Juvenile of commercially important fish species

Table 3.11: *Trend of volume of fish catch in the last season (2011-2012) compared to that before 2011.*

	Open season							
	Peak Period		Low Period		Closed season		All	
Trend	No.	(%)	No.	(%)	No.	(%)	No.	(%)
For general fish species								
Decreased	7	14	7	14	5	14.3	19	14.1
Unchanged	5	10	6	12	6	17.1	17	12.6
Increased	33	66	32	64	21	60.0	86	63.7
Increased much	5	10	5	10	3	8.6	13	9.6
Total	50	100	50	100	35	100.0	135	100.0
For small-sized fish species								
Decreased	6	12	8	16	5	14.3	19	14.1
Unchanged	5	10	5	10	5	14.3	15	11.1
Increased	34	68	32	64	23	65.7	89	65.9
Increased much	5	10	5	10	2	5.7	12	8.9
Total	50	100	50	100	35	100.0	135	100.0

Table 3.12: *Trend of price of fish in the last season (2011-2012) compared to that before 2011.*

	Open Season							
	Peak Period		Low Period		Closed Season		All	
Trend	No.	(%)	No.	(%)	No.	(%)	No.	(%)
For general fish species								
Decreased much	1	2	1	2	1	2.9	3	2.2
Decreased	35	70	35	70	22	62.9	92	68.1
Unchanged	3	6	3	6	3	8.6	9	6.7
Increased	11	22	11	22	9	25.7	31	23.0
Total	50	100	50	100	35	100.0	135	100.0
For small-sized fish species								
Decreased much	1	2	1	2	1	2.9	3	2.2
Decreased	34	68	34	68	21	60.0	89	65.9
Unchanged	4	8	4	8	4	11.4	12	8.9
Increased	11	22	11	22	9	25.7	31	23.0
Total	50	100	50	100	35	100.0	135	100.0

1.2 Fish Farmers

Table 3.13: *Age group distribution of respondent households by sex in all provinces.*

Age group (years)	Male		Female		Both	
	No.	(%)	No.	(%)	No.	(%)
20 - 30	5	12.5	0	0.0	5	12.5
31 - 40	8	20.0	1	2.5	9	22.5
41 - 50	13	32.5	2	5.0	15	37.5
51 - 60	7	17.5	3	7.5	10	25.0
61 and above	1	2.5	0	0.0	1	2.5
Total	34	85.0	6	15.0	40	100.0

Table 3.14: *Average years of experiences in fish farming by sex and type of fish farming system in all provinces.*

Types of fish farming systems	Male (n=34)			Female (n=6)			Both (n=40)		
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Pond	5.3	3	10	7.8	3	19	6.1	3	19
Cage	11.8	2	31	3.0	3	3	11.4	2	31
All	9.9	2	31	7.0	3	19	9.5	2	31

Table 3.15: *Percentage of fish farmers culturing fish by type of farming systems in all provinces.*

	Fish Species		Pond		Cage		All	
No.	Scientific name	Khmer name	No.	(%)	No.	(%)	No.	(%)
1	*Pangasianodon Hypophthalmus*	Pra Thom	5	6.4	11	14.1	16	20.5
2	*Pangasius Bocourti*	Pra Khchao	-	-	8	10.3	8	10.3
3	*Hemibagrus Wyckioides*	Khcha	-	-	8	10.3	8	10.3
4	*Wallago attu*	Sanday	-	-	6	7.7	6	7.7
5	*Brachirus spp.*	Andat Chhke	-	-	1	1.3	1	1.3
6	*Channa Micropeltes*	Chhdaur	9	11.5	6	7.7	15	19.2
7	*Clarias spp.*	Andeng	2	2.6	-	-	2	2.6
8	*Pangasius Conchophilus*	Kae/Pra Kae	-	-	8	10.3	8	10.3
9	*Pangasius Larnaudii*	Pou	-	-	5	6.4	5	6.4
10	*Leptobarbus Hoeveni*	Proloung	-	-	2	2.6	2	2.6
11	*Barbonymus Gonionotus*	Chhpin	-	-	1	1.3	1	1.3
12	*Barbonymus Schwanenfeldii*	Ka Hae	-	-	1	1.3	1	1.3
13	*Cirrhinus microlepis*	Prourl	-	-	1	1.3	1	1.3
14	*Osteochilus Melanopleurus*	Krum	-	-	1	1.3	1	1.3
15	*Henicorhynchus Siamensis*	Riel Tom	-	-	1	1.3	1	1.3
16	*Pseudolais Pleurotaenia*	Chhveat	-	-	1	1.3	1	1.3
17	*Cyclocheilichthys spp.*	Chhkok	-	-	1	1.3	1	1.3
Total			16	20.5	62	79.5	78	100.0

Table 3.16*: Average volume of fingerlings by species and type of fish culture per cycle.*

No.	Fish Species	Pond	Cage	All
1	Sanday	-	2,194.3	2,194.3
2	Khcha	-	2,259.3	2,259.3
3	Andat Chhke	-	3,000.0	3,000.0
4	Pra	59,166.7	3,746.2	21,247.4
5	Pou	-	8,090.9	8,090.9
6	Chhdau	1,777.8	2,416.7	2,033.3
7	Pra Khchao	-	6,277.8	6,277.8
8	Kae	-	8,400.0	8,400.0
9	Andeng	250,000.0	-	250,000.0
10	Proloung	-	2,750.0	2,750.0
11	Chhkok	-	4,500.0	4,500.0
12	Prourl	-	3,000.0	3,000.0
13	Krum	-	1,800.0	1,800.0
14	Chhpin	-	12,000.0	12,000.0
15	Riel Tom	-	8,000.0	8,000.0
16	Chhveat	-	1,800.0	1,800.0
17	Ka Hae	-	12,600.0	12,600.0
	All (per species)	38,812.5	4,925.7	11,230.2
	Total (All species)	41,400.0	13,792.0	24,145.0

Table 3.17*: Characteristics of fish farming by type of culture systems.*

Description	Pond	Cage	All
Area/Volume of aqua/fish culture (m^3/hh.)	12,306.4	165.7	4,718.4
No. of ponds/cages (unit/hh.)	1.1	1.7	1.5
No. of crops or cycles/year (time/year)	1.1	0.9	1.0
Time for each crop or cycle (month)	9.8	13.8	12.3
No. of fingerlings stocked (head)	41,400.0	13,792.0	24,145.0

Table 3.18: *Average volume of fingerlings by species and type of fish culture per cycle.*

No.	Fish Species	Pond	Cage	All
1	Sanday	-	2,194.3	2,194.3
2	Khcha	-	2,259.3	2,259.3
3	Andat Chhke	-	3,000.0	3,000.0
4	Pra Thom	59,166.7	3,746.2	21,247.4
5	Pou	-	8,090.9	8,090.9
6	Chhdaur	1,777.8	2,416.7	2,033.3
7	Pra Khchao	-	6,277.8	6,277.8
8	Kae/Pra Kae	-	8,400.0	8,400.0
9	Andeng	250,000.0	-	250,000.0
10	Proloung	-	2,750.0	2,750.0
11	Chhkok	-	4,500.0	4,500.0
12	Prourl	-	3,000.0	3,000.0
13	Krum	-	1,800.0	1,800.0
14	Chhpin	-	12,000.0	12,000.0
15	Riel Tom	-	8,000.0	8,000.0
16	Chhveat	-	1,800.0	1,800.0
17	Ka Hae	-	12,600.0	12,600.0
	Total	41,400.0	13,792.0	24,145.0

Table 3.19: *Average price of fingerlings (USD/head) by type of fish culture systems.*

No.	Fish Species	Pond	Cage	All
1	Sanday	-	0.39	0.39
2	Khcha	-	0.30	0.30
3	Andat Chhke	-	0.13	0.13
4	Pra Thom	0.02	0.16	0.12
5	Pou	-	0.14	0.14
6	Chhdaur	0.09	0.05	0.07
7	Pra Khchao	-	0.12	0.12
8	Kae/Pra Kae	-	0.08	0.08
9	Andeng	0.03	-	0.03
10	Proloung	-	0.06	0.06
11	Chhkork	-	0.15	0.15
12	Prourl	-	0.11	0.11
13	Krum	-	0.16	0.16
14	Chhpin	-	0.16	0.16
15	Riel Tom	-	0.16	0.16
16	Chhveat	-	0.11	0.11
17	Ka Hae	-	0.20	0.20
	All	0.06	0.17	0.15

Table 3.20: *Type of fingerlings selected to be cultured by fish species in all provinces.*

No.	Fish species	Wild		Hybrid/Hatchery		All	
		No.	(%)	No.	(%)	No.	(%)
1	Sanday	5	5.8	1	1.2	6	7.0
2	Khcha	1	1.2	8	9.3	9	10.5
3	Andat Chhke	1	1.2	-	-	1	1.2
4	Pra	6	7.0	12	14.0	18	20.9
5	Pou	7	8.1	4	4.7	11	12.8
6	Chhdaur	-	-	15	17.4	15	17.4
7	Pra Khchao	6	7.0	3	3.5	9	10.5
8	Kae/Pra Kae	7	8.1	-	-	7	8.1
9	Andeng	-	-	1	1.2	1	1.2
10	Proloung	2	2.3	-	-	2	2.3
11	Chhkork	1	1.2	-	-	1	1.2
12	Prourl	1	1.2	-	-	1	1.2
13	Krum	1	1.2	-	-	1	1.2
14	Chhpin	1	1.2	-	-	1	1.2
15	Riel Tom	1	1.2	-	-	1	1.2
16	Chhveat	1	1.2	-	-	1	1.2
17	Ka Hae	1	1.2	-	-	1	1.2
	All	42	48.8	44	51.2	86	100.0

Table 3.21: *Percentage distribution of sources of fingerlings in all provinces.*

No.	Sources	Own captured (wild)	Fishers (wild)	Hatcheries farms/ stations	Nursery sites	Other fish farmers	Imported (Vietnames, Thailand)	All
1	Sanday	-	50.0	-	-	50.0	-	100
2	Khcha	25.0	-	-	25.0	25.0	25.0	100
3	Andat Chhke	-	100.0	-	-	-	-	100
4	Pra Thom	15.8	11.8	19.7	19.7	18.1	14.8	100
5	Pou	10.0	15.0	-	25.0	25.0	25.0	100
6	Chhdaur	-	29.1	-	-	-	70.9	100
7	Pra Khchao	13.0	16.1	-	24.7	21.4	24.7	100
8	Kae/Pra Kae	25.0	33.3	-	-	41.7	-	100
9	Andeng	-	-	-	-	50.0	50.0	100
10	Proloung	50.0	-	-	-	50.0	-	100
11	Chhkork	-	-	-	-	100.0	-	100
12	Prourl	-	-	-	-	100.0	-	100
13	Krum	-	-	-	-	100.0	-	100
14	Chhpin	-	-	-	-	100.0	-	100
15	Riel Tom	100.0	-	-	-	-	-	100
16	Chhveat	100.0	-	-	-	-	-	100
17	Ka Hae	-	-	-	-	100.0	-	100
	All	19.9	15.0	1.2	5.6	46.0	12.4	100

Table 3.22: *Percentage of fish farmers choosing types of fish feed for their fish farming.*

Types of fish feed	No.	(%)
Freshwater small-sized fish (Fresh and dried)	40	44.9
Marine trash fish	12	13.5
Commercial/Pellet feed	6	6.7
Rice bran	24	27.0
Others*	7	7.9
Total	89	100.0

Note: ***Others***: bone &head of Pra, fish &chicken intestine, fish sauce germ, Kapok flour, &water spinach.

Table 3.23: *Percentage of fish feed supplying sources.*

Type of fish feed	Caught (%)	Bought (%)	Total
Freshwater small-sized fish (Fresh and dried	49.8	50.2	100
Marine trash fish	-	100.0	100
Commercial/Pellet	-	100.0	100
Rice bran	50.0	50.0	100
Others*	50.0	50.0	100
All	30.0	70.0	100

Note: ***Others***: bone &head of Pra, fish &chicken intestine, fish sauce germ, Kapok flour, &water spinach.

Table 3.24: *Trend of types of fish feed used for fish farming over the past 5 years.*

Trend	No.	(%)
Decreased	5	12.5
Unchanged	29	72.5
Increased	6	15.0
Total	40	100

Table 3.25: *Trend of volume of freshwater small-sized fish used as fish feed over the past 5 years.*

Trend	No.	(%)
Decreased	9	22.5
Unchanged	15	37.5
Increased	16	40.0
Total	40	100

Table 3.26: *Trend of price of freshwater small-sized fish used as fish feed over the past 5 years.*

Trend	No.	(%)
Decreased much	1	2.5
Decreased	23	57.5
Unchanged	5	12.5
Increased	11	27.5
Total	40	100

1.3 Fish Traders

***Table 3.27**: Age group distribution of respondent households by sex in all provinces.*

Age group (years)	Male		Female		Both	
	No.	(%)	No.	(%)	No.	(%)
20 – 30	3	6	8	16	11	22
31 – 40	11	22	2	4	13	26
41 – 50	8	16	9	18	17	34
51 – 60	4	8	4	8	8	16
61 and above	1	2	0	0	1	2
Total	27	54	23	46	50	100

***Table 3.28**: Average year experiences in fish trade by sex and type of traders in all provinces.*

	Male			Female			Both		
Type of traders	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Fish collectors/Middlemen	15.8	4	33	11.0	3	19	14.8	3	33
Wholesalers	15.1	3	50	17.8	1	33	15.8	1	50
Retailers	8.3	7	10	16.1	3	35	14.8	3	35
All	14.6	3	50	16.0	1	35	15.2	1	50

***Table 3.29**: Average volume of fresh fish traded per day (kg/day) by season in all provinces (2011-2012).*

	Open season				
Description	Peak Period	Low Period	All	Closed season	All
Both freshwater and marine fish	2,781.5	491.8	2,316.2	115.5	2,176.7
Freshwater fish (all species)	2,779.3	488.5	2,314.0	115.5	2,157.9
Freshwater small-sized fish	2,438.5	108.8	2,001.0	57.0	1,921.9

Table 3.30: *Average volume of fresh freshwater small-sized fish traded per day (kg/day) by season and species (2011-2012).*

Fish Species		Open season	Closed season	All
Scientific name	Khmer name			
1. *Henicorhynchus spp.*	Riel	1,438.6	11.7	1,415.3
2. *Mystus spp.*	Kanhchos	52.6	22.4	46.2
3. *Trichogaster spp.*	Komphleanh	108.4	32.8	94.6
4. *Thynnichthys thynnoides*	Linh	911.4	5.2	907.2
5. *Dangila spp.*	Khnorng Veng	37.5	2.0	30.6
6. *Cyclocheilichthys spp.*	Sraka Kdarm	6.0	5.6	5.8
7. *Clupeichthys spp.*	Bandol Ampov	550.4	-	550.4
8. *Yasuhikotakia spp.*	Kanhchrouk	113.9	0.2	110.6
9. *Osteochilus lini*	Kros	57.2	11.2	54.2
10. *Paralaubuca riveroi*	Sleuk Reussey	617.9	-	617.8
11. *Labiobarbus spp.*	Ach Kok	550.8	1.9	543.5
12. *Coilia spp.*	Chunlourn Moan	28.1	-	28.1
13. *Anabas testudineus*	Kranh	27.1	16.1	24.0
14. *Puntius rhombeus*	Angkat Prak	18.6	0.3	18.6
15. *Parachela spp.*	Chanteas Phlouk	302.0	-	302.0
16. *Kryptopterus moorei*	Komphleav	133.7	-	133.7
17. *Hyporhamphus limbatus*	Phtoung	3.8	-	2.6
18. *Acantopsis spp.*	Reus Chek*	8.1	-	8.1
19. *Opsarius koratensis*	Changva	21.7	-	21.7
20. *Parambassis spp.*	Kanhchanh Chrass	118.7	-	118.7
21. *Rasbora spp.*	Changva Moul	7.8	-	7.8
22. *Cirrhinus microlepis*	Kralang*	239.4	5.5	234.5
23. *Pangasius conchophilus*	Pra Kae/Kae*	1.2	-	1.2
24. *Ompok spp.*	Tror Oan*	0.5	3.0	1.8
25. *Trichogaster pectoralis*	Kanthor*	55.7	20.9	51.1
26. *Hypsibarbus spp.*	Chhpin*	28.1	23.7	24.6
27. *Puntioplites spp.*	Chrorkeng*	60.1	28.1	49.2
28. *Cyclocheilichthys spp.*	Chhkork*	13.4	7.9	11.5
29. *Pristolepis fasciata*	Kantrorb*	11.0	4.8	9.4
30. *Labeo chrysophekadion*	Kaek*	2.1	-	2.1
31. *Pangasianodon hypophthalmus*	Pra*	2.0	-	2.0
32. *Pteropangasius pleurotaenia*	Chhveat*	0.3	-	0.2
33. *Pangasius larnaudiei*	Pou*	1.2	-	1.2
34. *Hemibagrus spp.*	Chhlaing*	1.8	0.6	1.9
35. *Barbodes spp.*	Kahae*	0.5	-	0.5
36. *Belodontichthys truncates*	Klang Hai*	1.0	-	1.0
37. *Notopterus notopterus*	Slat*	6.5	-	4.8

38. *Micronema apogon spp.*	Kes*	2.9	0.3	2.6
Total		2,001.0	57.0	1,921.9

Note: *: Juvenile of commercially important fish species

***Table 3.31**: Average price of fresh freshwater small-sized fish (USD/kg) by season (2011-2012).*

Fish Species		Open season		Closed season		All	
Scientific name	Khmer name	B. price	S. price	B. price	S. price	B. price	S. price
1. *Henicorhynchus spp.*	Riel	0.3	0.4	0.8	1.0	0.4	0.5
2. *Mystus spp.*	Kanhchos	0.5	0.6	0.8	0.9	0.6	0.7
3. *Trichogaster spp.*	Komphleanh	0.2	0.3	0.5	0.6	0.4	0.5
4. *Thynnichthys thynnoides*	Linh	0.5	0.7	1.0	1.1	0.6	0.7
5. *Dangila spp.*	Khnangveang	0.4	0.4	1.0	1.1	0.4	0.5
6. *Cyclocheilichthys spp.*	Srorka Kdarm	0.3	0.4	0.4	0.6	0.3	0.4
7. *Clupeichthys spp.*	Bandol Ampov	0.2	0.3	-	-	0.2	0.3
8. *Yasuhikotakia spp.*	Kanhchrouk	0.4	0.5	0.3	0.4	0.4	0.5
9. *Osteochilus lini*	Kros	0.5	0.6	0.6	0.7	0.5	0.6
10. *Paralaubuca riveroi*	Sleuk Reussey	0.3	0.3	-	-	0.3	0.3
11. *Labiobarbus spp.*	Ach Kok	0.3	0.4	1.1	1.3	0.5	0.6
12. *Coilia spp.*	Chunlournh Moan	0.2	0.3	-	-	0.2	0.3
13. *Anabas testudineus*	Kranh	0.5	0.6	0.7	0.8	0.6	0.7
14. *Puntius rhombeus*	Angkat Prak	0.3	0.4	0.6	0.9	0.3	0.4
15. *Parachela spp.*	Chanteas Phlourk	0.3	0.4	-	-	0.3	0.4
16. *Kryptopterus moorei*	Komphleav	0.3	0.3	-	-	0.3	0.3
17. *Hyporhamphus limbatus*	Phtoung	0.3	0.3	-	-	0.3	0.3
18. *Acantopsis spp.*	Reus Chek*	0.5	0.7	-	-	0.5	0.7
19. *Opsarius koratensis*	Changva	0.3	0.5	-	-	0.3	0.5
20. *Parambassis spp.*	Kanchanh Chrass	0.1	0.2	-	-	0.1	0.2
21. *Rasbora spp.*	Changva Moul	0.3	0.4	-	-	0.3	0.4
22. *Cirrhinus microlepis*	Kralang*	0.2	0.3	0.8	0.9	0.4	0.5
23. *Pangasius conchophilus*	Pra Kae/Kae*	0.8	0.9	-	-	0.8	0.9
24. *Ompok spp.*	Tror Oan*	0.2	0.5	0.8	0.9	0.5	0.7
25. *Trichogaster pectoralis*	Kanthor*	0.9	1.0	0.9	1.0	0.9	1.0
26. *Hypsibarbus spp.*	Chhpin*	0.5	0.6	0.5	0.6	0.6	0.6
27. *Puntioplites spp.*	Chrorkeng*	0.5	0.7	0.8	0.9	0.6	0.8
28. *Cyclocheilichthys spp.*	Chhkok*	0.4	0.5	0.6	0.7	0.4	0.6
29. *Pristolepis fasciata*	Kantrorb*	0.5	0.6	0.5	0.7	0.5	0.6
30. *Labeo chrysophekadion*	Kaek*	0.3	0.4	-	-	0.3	0.4
31. *Pangasianodon hypophthalmus*	Pra*	0.2	0.5	-	-	0.2	0.5
32. *Pteropangasius pleurotaenia*	Chhveat*	0.6	0.7	-	-	0.6	0.7
33. *Pangasius larnaudiei*	Pou*	0.8	0.9	-	-	0.8	0.9
34. *Hemibagrus spp.*	Chhlaing*	0.5	0.8	1.8	2.0	0.7	1.0
35. *Barbodes spp.*	Kahae*	0.2	0.5	-	-	0.2	0.5
36. *Belodontichthys truncatus*	Klang Hai*	0.2	0.5	-	-	0.2	0.5
37. *Notopterus notopterus*	Slat*	0.5	0.6	-	-	0.5	0.6

38. *Micronema apogon spp.*	Kes*	0.4	0.5	0.5	0.6	0.4	0.6
All		0.4	0.5	0.7	0.8	0.4	0.6

Note: *: Juvenile of commercially important fish species; B.: Buying; S.: Selling; Exchange rate: USD 1=4,000 Riel

***Table 3.32**: Trend of fresh freshwater small-sized fish traded in 2011-2012.*

Description	Trend (%)					
	Volume (n=50)	Size (n=50)	Price (n=50)	Quality (n=50)	Convenience (n=50)	Information (n=50)
Decreased	28	10	64	6	50	12
Unchanged	10	68	16	54	22	48
Increased	50	20	20	40	28	40
Increased much	12	2	-	-	-	-
Total	100	100	100	100	100	100

***Table 3.33**: Average volume of processed fish traded per day (kg/day) by season in all provinces (2011-2012).*

Description	Open season			Closed season	All
	Peak period	Low period	All		
Processed freshwater fish (all species)	59.7	52.2	57.8	28.3	57.2
Processed freshwater small-sized fish	58.7	51.0	56.9	26.9	56.2

Note: Quantity of **smoked fish** was converted into kilogram by multiplying number of skewer with average weight of smoked fish per skewer (in average, 1 skewer = 7.5 g or 0.075 kg).

***Table 3.34**: Average volume of processed freshwater small-sized fish traded per day (kg/day) by type of products and season (2011-2012).*

Volume of products	Type of processed products				All
	Salted-dried (Brolark)	Smoked (Chha'eur)	Fermented (Pha'ork)	Paste (Pro'hoc)	
Volume traded in open season (kg/day)	-	12.9	23	39.5	56.9
Volume traded in closed season (kg/day)	5	4.1	15	14.4	26.9
All	5	10.2	24	39.5	56.2

Note: Quantity of **smoked fish** was converted into kilogram by multiplying number of skewer with average weight of smoked fish per skewer (in average, 1 skewer = 7.5 g or 0.075 kg).

***Table 3.35**: Average price of processed freshwater small-sized fish (USD/kg) by type of products and season (2011-2012).*

Description	Type of processed products Salted-dried (Brolark)	Smoked (Chha'eur)	Fermented (Pha'ork)	Paste (Pro'hoc)
In open season				
Buying price (USD/kg)	-	3.7	0.8	0.7
Selling price (USD/kg)	-	4.0	1.5	1.0
In closed season				
Buying price (USD/kg)	0.5	4.5	0.7	0.9
Selling price (USD/kg)	0.8	5.0	1.6	1.3
All				
Buying price (USD/kg)	0.5	4.1	0.8	0.8
Selling price (USD/kg)	0.8	4.4	1.5	1.1

* **Note:** - Exchange rate: USD 1 = 4,000 Riel
- Quantity of **smoked fish** was converted into kilogram by multiplying number of skewer with average weight of smoked fish per skewer (in average, 1 skewer = 7.5 g or 0.075 kg)
- Average price of smoked fish ranges from USD 0.28 to 0.38 per skewer

***Table 3.36**: Trend of processed freshwater small-sized fish traded (2011-2012).*

Description	Trend (%) Volume (n=5)	Size (n=5)	Price (n=5)	Quality (n=5)	Convenience in trading (n=5)	Information on trading (n=5)
Decreased much	-	-	-	-	-	-
Decreased	41.7	-	16.7	-	16.7	-
Unchanged	25.0	91.7	41.7	91.7	8.3	41.7
Increased	33.3	8.3	33.3	8.3	75.0	58.3
Increased much	-	0.0	8.3	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0

1.4 Fish Exporters

Table 3.37*: Age group distribution of respondent households by sex.*

Age group (years)	Male		Female		Both	
	No	(%)	No	(%)	No	(%)
20 - 30	0	0	1	20	1	20
31 - 40	1	20	1	20	2	40
51 - 60	1	20	1	20	2	40
Total	2	40	3	60	5	100

Table 3.38*: Average years of experiences in fish export by sex.*

	Average years of experiences in fish export (no. year)								
	Male			Female			Both		
Type of fish	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
All fish species	17	5	29	11.3	5	22	13.6	5	29
Small-sized fish	14	5	23	11.3	5	22	12.4	5	23
All	15.5	5	26	11.3	5	22	13	5	26

Table 3.39*: Average volume of fresh freshwater small-sized fish traded per day (kg/day) by season (2011-2012).*

	Open season				
Description	Peak period	Low period	All	Closed season	All
Volume of fresh freshwater fish (all species) (kg/day)	3,166.7	1,100.0	2,728.5	250	2,672.2
Volume of fresh freshwater small-sized fish (kg/day)	1,900.0	233.3	1,556.3	50	1,526.9

Table 3.40*: Average volume of fresh freshwater small-sized fish exported per day (kg/day) by species and season (2011-2012).*

Fish Species		Open season	Closed season	All
Scientific name	Khmer name			
1. *Henicorhynchus spp.*	Riel	267.4	-	267.4
2. *Mystus spp.*	Kanhchos	623.9	-	623.9
3. *Trichogaster spp.*	Kompleanh	891.3	-	891.3
4. *Yasuhikotakia spp.*	Kanhchrouk	471.6	-	446.9
5. *Puntioplites spp.*	Chrorkeng*	445.7	-	445.7
6. *Kryptopterus moorei*	Kompleav	148.2	10	121.6
7. *Acantopsis spp.*	Reus Check*	534.0	-	534.0
8. *Macrognathus spp.*	Chhlonh*	267.0	-	267.0
9. *Notopterus notopterus*	Slat*	102.6	40	90.5
10. *Coilia spp.*	Chunlournh Moan	445.7	-	445.7
Total		1,556.3	50	1,526.9

Note: * Juvenile of commercially important fish species

Table 3.41*: Average price of fresh freshwater small-sized fish (USD/kg) by species and season (2011-2012).*

Fish Species		Open season		Closed season		All	
Scientific name	Khmer name	B. price	S. price	B. Price	S. price	B. price	S. price
1. *Henicorhynchus spp.*	Riel	0.3	0.4	-	-	0.3	0.4
2. *Mystus spp.*	Kanhchos	0.4	0.5	-	-	0.4	0.5
3. *Trichogaster spp.*	Kompleanh	0.3	0.3	-	-	0.3	0.3
4. *Yasuhikotakia spp.*	Kanhchrouk	0.6	0.8	-	-	0.6	0.8
5. *Puntioplites spp.*	Chrorkeng*	0.4	0.5	-	-	0.4	0.5
6. *Kryptopterus moorei*	Kompleav	1.5	1.6	1.8	1.9	1.7	1.7
7. *Acantopsis spp.*	Reus Check*	1.4	1.6	-	-	1.4	1.6
8. *Macrognathus spp.*	Chhlonh*	0.9	1.1	-	-	0.9	1.1
9. *Notopterus notopterus*	Slat*	0.8	1.0	2.8	2.9	1.8	1.9
10. *Coilia spp.*	Chunlournh Moan	0.2	0.2	-	-	0.2	0.2
Total		0.7	0.9	2.3	2.4	1.0	1.1

Note: * Juvenile of commercially important fish species
Exchange rate: USD 1 = 4,000 Riel

Table 3.42: *Trend of fresh freshwater small-sized fish exported in 2011-2012 compared to that before 2011.*

Description	Trend (%)						
	Volume (n=3)	Size (n=3)	Price (n=3)	Quality (n=3)	Convenience in exporting (n=3)	Information on exporting (n=3)	All (n=3)
Decreased much	-	-	-	-	33.3	-	5.6
Decreased	33.3	-	66.7	-	33.3	-	22.2
Unchanged	-	66.7	-	100	33.3	66.7	44.4
Increased	33.3	33.3	33.3	-	-	33.3	22.2
Increased much	33.3	-	-	-	-	-	5.6
Total	100.0	100.0	100.0	100	100.0	100.0	100.0

Table 3.43: *Average volume of processed freshwater small-sized fish exported per day by season and type of product (2011-2012).*

Description	Salted (Brolark)	Fish paste (Pro'hoc)	All
Volume exported in open season (kg/day)	20,000	10,000	15,000
Volume exported in closed season (kg/day)	4,000	-	4,000
All	19,584	10,000	14,792

Table 3.44: *Average price of processed freshwater small-sized fish exported (USD/kg) by season and type of product (2011-2012).*

Description	Salted (Brolark)	Fish paste (Pro'hoc)	All
In open season (USD/day)			
Buying price	0.28	0.40	0.34
Selling price	0.45	0.55	0.50
In closed season (USD/kg)			
Buying price	0.30	-	0.30
Selling price	0.50	-	0.50
All			
Buying price	0.29	0.40	0.34
Selling price	0.48	0.55	0.51

* **Note**: Exchange rate: USD 1 = 4,000 Riel

1.5 Fish Processors

***Table 3.45**: Age group distribution of respondent households by sex in all provinces.*

Age group (years)	Male No.	Male (%)	Female No.	Female (%)	Both No.	Both (%)
31 - 40	1	9.1	0	0.0	1	9.1
41 - 50	0	0.0	5	45.5	5	45.5
51 - 60	1	9.1	2	18.1	3	27.3
61 and above	2	18.2	0	0.0	2	18.1
Total	4	36.4	7	63.6	11	100.0

***Table 3.46**: Average years of experiences in fish processing by sex and type of fish processing operation.*

Type of fish processing	Average years of experiences in fish processing activities (no. year)								
	Male			Female			Both		
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Household	12	12	12	22.6	10	32	18.6	10	32
Private company	24	24	24	6	6	6	12	6	24
All	15	12	24	18	6	32	16.8	6	32

***Table 3.47**: Duration for processing freshwater small-sized fish per year by type of products in 2011.*

Description	Type of products					All
	Salted-dried	Smoked	Fermented	Paste	Fish sauce	
No. of months (month/year)	10	2.5	4.7	4.4	12	5.7
No. of days (day/month)	30	9	15.7	19.3	25	18.7
Time of one processing cycle (day/time)	1.5	2	62.0	44.3	1	30.7

Table 3.48: Volume of raw materials for fish processing, and final products (kg) per year.

Volume	Avg.	Min.	Max.
Raw materials			
All raw materials (kg/year)	358,360	900	888,360
Freshwater small-sized fish (kg/year)	208,400	900	500,000
Final products			
All final products (kg, L/year)	237,448	300	900,000
Final small-sized fish products (kg, L/year)	210,957	300	900,000

Note: Volume of fish sauce: 1 L = 1 kg

Table 3.49: *Species, volume and price of freshwater small-sized fish bought per month in 2011.*

Fish species		Volume (kg/month)			Buying price (USD/kg)		
Scientific name	Khmer name	Avg.	Min.	Max.	Avg.	Min.	Max.
1. *Henicorhynchus spp.*	Riel	112,654.0	450	420,000	0.36	0.15	0.88
2. *Mystus spp.*	Kanhchos	5,000.0	5,000	5,000	0.25	0.25	0.25
3. *Trichogaster spp.*	Komphleanh	79,719.4	180	380,000	0.40	0.20	0.55
4. *Thynnichthys thynnoides*	Linh	90,000.0	90,000	90,000	0.25	0.25	0.25
5. *Clupeichthys spp.*	Bandoul Ampov	2,000.0	2,000	2,000	0.38	0.38	0.38
6. *Yasuhikotakia spp.*	Kanhchrouk	8,357.0	1,714	15,000	0.25	0.25	0.25
7. *Osteochilus lini*	Kros	1,750.0	1,750	1,750	0.55	0.55	0.55
8. *Paralaubuca riveroi*	Sleuk Reussey	15,620.0	4,000	30,000	0.30	0.15	0.50
9. *Cyclocheilichthys spp.*	Chhkok*	1,750.0	1,750	1,750	0.55	0.55	0.55
10. *Labiobarbus spp.*	Ach Kok	15,000.0	15,000	15,000	0.25	0.25	0.25
11. *Coilia spp.*	Chunlournh Moan	500.0	500	500	0.38	0.38	0.38
12. *Pteropangasius pleurotaenia*	Chhveat	3,036.5	500	5,573	0.75	0.38	1.13
13. *Parachela spp.*	Chunteas Phlouk	20.0	20	20	0.25	0.25	0.25
	Total	145,286.4	200	420,000			

Note: * Juvenile of commercially important fish species
Exchange rate: USD 1 = 4,000 Riel

Table 3.50: *Volume of final processed products (kg) per year by type of products.*

Volume	Avg.	Min.	Max.
Salted-dried fish (Trey Brolark)	242,466.7	9,000	500,000
Smoked fish (Trey Chha'oeur)	7,100	300	20,000
Fermented fish (Pho'ork)	17,800	1,000	48,000
Fish paste (Mam/Pro' hoc)	113,729	1,500	320,000
Fish sauce (Teuk Trey)	900,000	900,000	900,000

Note: Conversion ratio of the products is:
- **1**:**0.5** for salted dried fish
- **1**:**0.075** for smoked fish
- **1**:**0.4** for fermented fish
- **1**:**0.3** for fish paste
- **1**:**3** for fish sauce

***Table 3.51**: Detailed information on selling processed freshwater small-sized fish per year by type of products in 2011.*

Description	Type of products					All
	Salted-dried	Smoked	Fermented	Paste	Fish sauce	
No. of selling months (month/year)	10.0	2.5	4.7	7.9	12.0	7.6
No. of selling times (time/month)	22.5	22.5	25.0	16.6	25.0	17.1
Volume sold (kg/time)	175.0	559.0[a]	426.7	6,661.1	8,000.0	5,157.6
Average selling price (USD/kg)	1.0	0.3[b]	1.0	0.9	0.5	0.8

<u>**Note**</u>: a: no. of skewer (1 skewer = 0.075 kg)
b: price per skewer

***Table 3.52**: Trend of fish processing for raw materials in 2011-2012 compared to that before 2011.*

Trend	Type of products					All
	Fresh	Salted-dried	Smoked	Fermented	Paste	
Type of product						
Decreased	22.2	-	-	-	-	12.5
Unchanged	22.2	33.3	-	-	-	18.8
Increased	33.3	66.7	100	100	100	56.3
Increased much	22.2	-	-	-	-	12.5
Total	100.0	100.0	100	100	100	100.0
Supply/Demand						
Unchanged	44.4	66.7	-	-	-	37.5
Increased	33.3	33.3	100	100	100	50.0
Increased much	22.2	-	-	-	-	12.5
Total	100.0	100.0	100	100	100	100.0
Volume						
Decreased	33.3	33.3	-	-	-	25.0
Unchanged	11.1	33.3	-	-	-	12.5
Increased	44.4	33.3	100	100	100	56.3
Increased much	11.1	-	-	-	-	6.3
Total	100.0	100.0	100	100	100	100.0

Table 3.53: *Trend of fish processing for processed products in 2011-2012 compared to that before 2011.*

Trend	Type of products					
	Salted-dried	Smoked	Fermented	Paste	Fish sauce	All
Type of product						
Decreased	50	100.0	-	37.5	-	41.2
Unchanged	50	-	100.0	37.5	-	41.2
Increased	-	-	-	12.5	100	11.8
Increased much	-	-	-	12.5	-	5.9
Total	100	100.0	100.0	100.0	100	100.0
Supply/Demand						
Decreased	50	66.7	66.7	25.0	-	41.2
Unchanged	50	33.3	33.3	50.0	-	41.2
Increased	-	-	-	12.5	100	11.8
Increased much	-	-	-	12.5	-	5.9
Total	100	100.0	100.0	100.0	100	100.0
Volume						
Decreased	50	66.7	100.0	50.0	-	58.8
Unchanged	50	33.3	-	12.5	-	17.6
Increased	-	-	-	25.0	100	17.6
Increased much	-	-	-	12.5	-	5.9
Total	100	100.0	100.0	100.0	100	100.0

1.6 Fish Consumers

Table 3.54: *Age group distribution of respondent households by sex in all provinces.*

Age group (years)	Male		Female		Both	
	No	(%)	No	(%)	No	(%)
20 - 30	3	6	6	12	9	18
31 - 40	3	6	7	14	10	20
41 - 50	10	20	4	8	14	28
51 - 60	7	14	7	14	14	28
61 and above	1	2	2	4	3	6
Total	24	48	26	52	50	100

Table 3.55: *Volume of freshwater small-sized fish consumed per year (kg/year) by type of consumers and province.*

Province	Fishermen			Non-Fishermen			Both		
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Kampong Chhnang	244.1	19	494.2	228.8	87.3	576	238.0	19	576
Battambang	-	-	-	107.4	24.0	174	107.4	24	174
Siem Reap	174.1	120	244.0	167.0	24.0	286	169.8	24	286
Kandal	233.5	90	480.0	364.0	364.0	364	259.6	90	480
Phnom Penh	262.6	26	480.0	275.8	24.0	921	267.7	24	921
All	231.0	19	494.2	195.8	24.0	921	213.4	19	921

Table 3.56: *Preferable type of processed freshwater small-sized fish by type of consumers.*

Type of product	Fishermen		No-fishermen		All	
	No.	(%)	No.	(%)	No.	(%)
Fresh fish	25	13.6	22	12.0	47	25.5
Salted-dried fish	18	9.8	15	8.2	33	17.9
Smoked fish	17	9.2	18	9.8	35	19.0
Fermented fish	19	10.3	13	7.1	32	17.4
Fish paste	20	10.9	17	9.2	37	20.1
Total	99	53.8	85	46.2	184	100.0

Table 3.57: *Detailed information on purchasing and consuming freshwater small-sized fish by type of products.*

Description	Type of products Fresh	Salted-dried	Smoked	Fermented	Paste
Frequency of buying products (day/time)	3.8	4.1	49.2	88.6	104.1
Distance to buy products (m)	172.7	191.9	231.0	125.5	116.6
Volume of products bought per time (kg/time)	0.7	0.7	3.1[a]	5.7	7.6
Average price per kg (USD/kg)	0.9	0.9	0.3[b]	1.6	1.7
Highest price per kg (USD/kg)	1.3	1.3	0.4[b]	1.9	2.0
Lowest price per kg (USD/kg)	0.4	0.5	0.3[b]	1.3	1.4

Note: a: no. of skewer (1 skewer = 0.075 kg)
b: price per skewer

Table 3.58: *Perception of consumers on freshwater small-sized fish by type of products.*

Description	Type of products (%) Fresh (n=50)	Salted-dried (n=50)	Smoked (n=50)	Fermented (n=50)	Paste (n=50)	All
Quality						
Bad	6.4	6.1	5.1	3.1	-	4.3
Medium	48.9	66.7	56.4	59.4	56.8	56.9
Good	40.4	27.3	35.9	34.4	37.8	35.6
Very Good	4.3	-	2.6	3.1	5.4	3.2
Total	100.0	100.0	100.0	100.0	100.0	100.0
Convenience in consuming						
Bad	6.4	9.1	7.7	3.1	2.7	5.9
Medium	36.2	51.5	48.7	53.1	51.4	47.3
Good	46.8	36.4	38.5	40.6	40.5	41.0
Very Good	10.6	3.0	5.1	3.1	5.4	5.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
Information on supply and use						
Bad	12.8	12.1	7.7	6.3	5.4	9.0
Medium	46.8	57.6	53.8	65.6	59.5	55.9
Good	38.3	30.3	38.5	28.1	35.1	34.6
Very Good	2.1	-	-	-	-	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.59: *Trend of freshwater small-sized fish consumption by type of products.*

Trend	Type of products Fresh (n=50)	Salted-dried (n=50)	Smoked (n=50)	Fermented (n=50)	Paste (n=50)	All
Buying volume						
Decreased	14.9	18.2	15.4	15.6	10.8	14.9
Unchanged	57.4	66.7	69.2	65.6	62.2	63.8
Increased	27.7	15.2	15.4	18.8	27.0	21.3
Total	100.0	100.0	100.0	100.0	100.0	100.0
Size						
Decreased	6.4	9.1	10.3	6.3	5.4	7.4
Unchanged	68.1	63.6	76.9	75.0	67.6	70.2
Increased	23.4	24.2	12.8	18.8	24.3	20.7
Increased much	2.1	3.0	-	-	2.7	1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
Price						
Decreased	46.8	45.5	23.1	56.3	45.9	43.1
Unchanged	23.4	27.3	51.3	31.3	32.4	33.0
Increased	29.8	27.3	25.6	12.5	21.6	23.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
Quality						
Decreased	4.3	6.1	5.1	6.3	2.7	4.8
Unchanged	68.1	60.6	66.7	71.9	73.0	68.1
Increased	27.7	33.3	28.2	21.9	24.3	27.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Convenience in consuming						
Decreased	6.4	6.1	2.6	6.3	2.7	4.8
Unchanged	48.9	51.5	59.0	50.0	54.1	52.7
Increased	38.3	39.4	28.2	37.5	35.1	35.6
Increased much	6.4	3.0	10.3	6.3	8.1	6.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
Information on supply and use						
Decreased much	2.1	-	-	3.1	2.7	1.6
Decreased	8.5	15.2	10.3	3.1	5.4	8.5
Unchanged	59.6	57.6	59.0	56.3	48.6	56.4
Increased	27.7	24.2	28.2	34.4	37.8	30.3
Increased much	2.1	3.0	2.6	3.1	5.4	3.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

II. Value Chain Analysis and Marketing Channel of Freshwater Small-sized Fish

2.1 Fishermen

***Table 3.60**: Methods used by fishers to market their fish by type of fishing in all provinces.*

	Small scale		Large sale/Bag net		All	
Description	No.	(%)	No.	(%)	No.	(%)
Carry to markets and sell directly to consumers	9	14.1	-	-	9	14.1
Carry to landing sites and sell to wholesalers	17	26.6	1	1.6	18	28.1
Middlemen/collectors buy the fish from fishing grounds	14	21.9	2	3.1	16	25.0
Middlemen/collectors buy the fish from villages	13	20.3	-	-	13	20.3
Sell fish directly to neighboring consumers at home	8	12.5	-	-	8	12.5
Total	61	95.3	3	4.7	64	100.0

***Table 3.61**: Percentage of freshwater small-sized fish distribution (% of volume) and by season in all provinces.*

	Open season			
Types of fish buyers	Peak period	Low period	Closed season	All
Consumption (food)	2.3	2.5	4.4	3.2
End consumers	12.5	17.8	19.7	18.0
Local fish traders/collectors/middlemen	29.8	22.8	24.6	25.6
Provincial traders/collectors/middlemen	13.0	22.2	25.7	15.9
Fish farmers (animal/fish feed)	15.3	11.1	25.7	14.0
Processors	25.1	22.2	-	21.7
Exporter	1.9	1.4	-	1.6
Total	100.0	100.0	100.0	100.0

***Table 3.62**: Trend of freshwater small-sized fish distribution by season in all provinces.*

	Open Season							
	Peak Period		Low Period		Closed season		All	
Trend	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Decreased	7	14	6	12	3	8.6	16	11.9
Unchanged	23	46	26	52	19	54.3	68	50.4
Increased	19	38	17	34	13	37.1	49	36.3
Increased much	1	2	1	2	-	-	2	1.5
Total	50	100	50	100	35	100.0	135	100.0

2.2 Fish Traders

***Table 3.63**: Percentage distribution of demanding sources of processed freshwater small-sized fish by type of products (2010-2011).*

	Type of processed products				
Source of buyers	Salted-dried (n=50)	Smoked fish (n=50)	Fermented (n=50)	Fish paste (n=50)	All (n=50)
End consumers	40	10	23.9	27.7	23.1
Local retailers	60	90	31.3	29.8	33.7
Middlemen/Collectors/Wholesalers	-	-	44.8	42.6	43.3
Total	100	100	100.0	100.0	100.0

2.3 Fish Processors

Table 3.64*: Supplying sources of freshwater small-sized fish per month in 2011 (% of volume).*

Fish species		Supplying sources			
Scientific name	Khmer name	Fishers	Collectors/ Middlemen	Other processors	Total
1. *Henicorhynchus spp.*	Riel	4.2	6.0	6.3	16.5
2. *Mystus spp.*	Kanhchos	-	-	6.3	6.3
3. *Trichogaster spp.*	Komphleanh	2.1	5.8	6.3	14.2
4. *Thynnichthys thynnoides*	Linh	-	6.3	-	6.3
5. *Clupeichthys spp.*	Bandoul Ampov	-	6.3	-	6.3
6. *Yasuhikotakia spp.*	Kanhchrouk	-	6.3	-	6.3
7. *Osteochilus lini*	Kros	-	6.3	-	6.3
8. *Paralaubuca riveroi*	Sleuk Reussey	-	6.3	-	6.3
9. *Cyclocheilichthys spp.*	Chhkok	-	6.3	-	6.3
10. *Labiobarbus spp.*	Ach Kok	-	6.3	-	6.3
11. *Coilia spp.*	Chunlournh Morn	-	6.3	-	6.3
12. *Pteropangasius pleurotaenia*	Chhveat	-	6.3	-	6.3
13. *Parachela spp.*	Chunteas Phlouk	-	6.3	-	6.3
Total		6.3	74.8	18.9	100.0

Table 3.65*: Percentage distribution of demanding sources of processed freshwater small-sized fish (% of volume) by type of products.*

Description	Type of products					All
	Salted-dried	Smoked	Fermented	Paste	Fish sauce	
Household consumption	4.7	1	0.5	1.1	-	1.4
End consumers (direct selling)	9.3	-	-	23.8	-	15.3
Collectors/Middlemen	-	-	49.9	27.5	-	30.6
Wholesalers/Retailers	86.0	99	49.6	36.6	100	40.5
Other processors	-	-	-	11.0	-	12.2
Total	100.0	100	100.0	100.0	100	100.0

2.4 Consumers

***Table 3.66**: Percentage distribution of supplying sources of freshwater small-sized fish by type of products (% of volume).*

Supplying sources	Type of products					
	Fresh	Salted-dried	Smoked	Fermented	Paste	All
Fishers	20.8	25.0	20.8	24.7	24.4	23.1
Retailers	35.5	36.2	27.7	24.3	25.9	29.9
Processors	-	-	28.6	25.5	22.6	15.3
Own catch	43.7	-	-	-	-	8.7
Own process	-	38.8	22.8	25.5	27.1	22.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

III. Perception and Challenges/Constraints of Chain Actors

Table 3.67: *Plan of traders in the trade of fresh and processed freshwater small-sized fish.*

Plan	No.	(%)
Change		
Expand	13	26
Reduce	9	18
No change	27	54
Others	1	2
Total	50	100

Table 3.68: *Plan of exporters in the trade of fresh and processed freshwater small-sized fish.*

Plan	No.	(%)
Change (reduce)	4	80
No change	1	20
Total	5	100

Table 3.69: *Perception of processors on development trend of freshwater small-sized fish processing industry in the coming time.*

Perception	No.	%
Decrease	2	18.2
Unchanged	3	27.3
Increase	6	54.5
Total	11	100.0

Table 3.70: *Plan of processors for major changes in processing of freshwater small-sized fish.*

Plan	No.	(%)
Change		
Expand	3	27.3
Reduce	4	36.4
No change	4	36.4
Total	11	100.0

Table 3.71: *Plan on consumption of fresh/processed small-sized fish in the coming time.*

Plan	No.	%
Change	16	32
No change	34	68
Total	50	100

TOPIC AREA:
VALUE CHAIN ANALYSIS
❖

VALUE CHAIN ANALYSIS FOR BLACK COCKLES (*ANADARA TUBERCULOSA* AND *A. SIMILIS*) IN NICARAGUA

Marketing, Economic Risk Assessment & Trade/Study/09MER10UH

FINAL INVESTIGATION REPORT
Printed as submitted in Spanish

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RESUMEN

Este estudio tiene como propósito entender cómo se realiza la comercialización de la concha negra, qué procesos ocurren y quienes los realizan, como se coordinan las actividades –regulación formal e informal- y cómo se agrega el valor; todo ello con el fin de reforzar las medidas de desarrollo territorial que ha venido acompañando el Instituto de Capacitación, Investigación y Desarrollo Ambiental de la Universidad Centroamericana (Instituto CIDEA-UCA). Para obtener esta información se utilizó una encuesta diseñada para cada uno de los eslabones identificados en la primera parte del estudio que consistió en una revisión de literatura. Se identificaron dos eslabones adicionales a los cuatro sugeridos en la literatura, tres tipos de actores en la intermediación, baja nivel de organización entre los concheros lo que impide reducir los costos de para el aprovechamiento de la concha, poca coordinación lo que lleva a que en los diferentes eslabones se repitan las actividades, los cuales no son muy diversas. En si la es una cadena de bajo valor agregado a lo largo de la cadena ya que la concha no pasa por un proceso real de transformación, sino que se sigue consumiendo de forma tradicional –semi-cruda, o es utilizada como un elemento en platillos no muy sofisticados. Por otro lado, se identificó que la coordinación es baja, pero a pesar de esto, los intermediarios son quienes juegan el papel de coordinador.

INTRODUCCIÓN

El presente estudio surge de la colaboración entre la Universidad de Hawaii y el Instituto de Capacitación Investigación y Desarrollo Ambiental (CIDEA), en el desarrollo del Programa "Human health and aquaculture: Health Benefits through improving aquaculture sanitation and best management practices (CRSP)" y tiene como objetivo analizar la cadena de valor de las conchas negras para:

1. Examinar las acciones a seguir para incentivar la agregación de un mayor valor del producto
2. Identificar los circuitos de comercialización de los actores involucrados en los diferentes procesos y cómo se coordinan estos actores
3. Evaluar el impacto en el desarrollo territorial que ha surgido del acompañamiento del Instituto CIDEA-UCA y otros actores que trabajan sobre la temática de la concha negra

La extracción de conchas negras es una actividad de hogares en extrema pobreza, que trabajan en los manglares de forma artesanal y dependen de actores extraterritoriales para comercializar el producto. Por lo tanto, reducir la dependencia de actores territoriales o los niveles de intermediación de las conchas negras puede mejorar los ingresos y disminuir la pobreza de las familias concheras. La agregación de valor en la cadena de las conchas negras implica comercializar productos certificados por su inocuidad en la depuración y el procesamiento, lo que puede disminuir las enfermedades transmitidas por alimentos (ETA) que tienen un alto costo para el sistema público de salud, porque el consumo de alimentos contaminados provoca infecciones gastrointestinales leves, severas o inclusive la muerte.

La promoción de procesos de desarrollo a nivel local con base en productos del mar, y específicamente en el caso de las conchas, demanda conocer los aspectos relacionados a este mercado. Esto incluye los diferentes estándares de calidad con que demandan los productos los procesadores finales, y los encadenamientos existentes desde la extracción hasta el consumidor final, con precios, márgenes de ganancia y márgenes de ampliación de oferta/demanda. Finalmente, se necesita conocer la factibilidad de procesos de integración ya sea vertical y/o horizontal para incrementar los niveles de competitividad y/o apropiación del valor generado en el proceso.

En este sentido, el trabajo pretende entender cómo se realiza la comercialización, quiénes la realizan, qué tipo de relaciones se dan y cómo se distribuyen los beneficios. La información generada contribuirá a la toma de decisiones, acerca de qué medidas deben ser incorporadas en la promoción de un desarrollo territorial y la implementación del "Plan estratégico de desarrollo del sector conchero 2012-2016" que ha venido acompañando el Instituto de Capacitación, Investigación y Desarrollo Ambiental de la Universidad Centroamericana (CIDEA-UCA), el Instituto Nicaragüense de la Pesca (INPESCA), la Fundación Amigos del Río San Juan, la Universidad Nacional Autónoma de León y otros agentes que trabajan la temática de las conchas negras.

Para lograr tal fin, se utiliza el enfoque de cadena de valor, que permite analizar la diversidad de actores a través de las actividades que realiza cada uno de ellos en el proceso de llevar un producto hasta el consumidor final (Kaplinsky& Morris, 2000) y la coordinación que existente entre ellos para la agregación de valor y garantizar los requisitos que el consumidor o la regulación formal demanda.

Este estudio presenta el mapa de los actores agrupados en los procesos que se dan a lo largo de la cadena y la gobernanza de la cadena. En la gobernanza se estudian los requisitos que se deben cumplir tanto por regulación formal –leyes y regulaciones nacionales sobre la concha y relacionados- e informal –definida por las relaciones entre actores.

Las conchas comúnmente conocidas como conchas negras o prietas son en realidad dos especies de moluscos bivalvos diferentes, *Anadara tuberculosa* y *Anadara similis* que forman parte de la familia Anadarinae (López. 2004. P.13). Por tanto, ambas viven en zonas fangosas de poca profundidad (IMARPE, s.f) y además tienen la característica de ser sedentarios, en consecuencia obtienen su alimentación de la filtración de las partículas de agua (Becerra, s.f).

Por la vida sedentaria que tienen y la forma de la que obtienen su alimentación, las zonas de manglares entre Laguna de Ballena en el Golfo de California y Tumbes, Perú (USAID, 2009; Lazarich, Rivas, Arguello, 2009; IMARPE, s.f) forman su hábitat natural ya que son zonas fangosas con agua poco profunda y con gran cantidad de nutrientes (Becerra, s.f.)

El consumo de la concha negra según Ammour (1999) está asociado con la cultura y tradición de los pueblos indígenas ubicados a lo largo de la costa del pacífico, lo que puede explicar porque su mayor mercado se encuentra entre la frontera de Perú y Ecuador (USAID, 2009), y porque en Europa se consumen más los bivalvos como ostra (O. edulis), el mejillón común (M. edulis), el mejillón mediterráneo (M. galloprovincialis), el berberecho (C. edule), la viera (P. maximus), almejas y la babosa (V. pullastra) (Becerra, s.f).

La extracción y recolección de la concha, es una actividad que no requiere de gran inversión de tecnología ni de tiempo debido a que la extracción se hace de forma manual y solo requiere de un saco o bolsa (Poma, 1981; citado en IMARPE) llamada matata donde se colocan las conchas hasta el momento de la venta; para obtener la concha los concheros recorren los estuarios durante la marea baja por tres o cuatro horas al día. Por estas características Mackenzie y Buesa (2006, citados en USAID, 2009) consideran que es una actividad realizada por personas pobres y con condiciones de vida limitada.

La explotación de las conchas Anadara –*tuberculosa* y *similis*, como actividad económica generadora de riqueza enfrenta retos para su sostenibilidad y crecimiento. El primero de ellos consiste en lo que se ha llamado *el problema de los comunes,* es decir que por ser un recurso de libre acceso, cualquiera que esté dispuesto a meterse al fango puede realizarla (USAID, 2009), y dada la carencia de derechos de propiedad nadie puede impedir que extraiga tantas conchas como desee, lo que lleva a una explotación más allá de la capacidad de reproducción, lo que pone a la concha en peligro de extinción.

Un segundo reto es la sostenibilidad económica y posibilidad de mejorar la condición de vida de las personas que se dedican al concheo[2]. La disminución de la disponibilidad de la concha producto del agotamiento por la sobre explotación tiene consecuencias económicas, como disminución del ingreso producto de la entrada de más personas y con el agotamiento de la concha, el tamaño de la concha es cada vez menor y por tanto el precio de la concha disminuye (Mera, 1999).
Un tercer reto es la distribución de poder de negociación en la comercialización de la concha. Lo remoto de la comunidades donde se conchea y la falta de organización de los concheros, son factores clave en el limitado acceso a los mercados y baja capacidad para conservar la concha de manera higiénica por mucho tiempo, limitando su capacidad de negociación. En consecuencia los intermediarios, en sus diferentes niveles pueden imponer precios y requisitos (Mera, 2009; USAID, 2009).

En algunos casos la presencia de compras a futuro que realizan los intermediarios y el canje de conchas por productos para el hogar y alimentos, llevan a que entre el conchero y los intermediarios se creen vínculos fuertes, que presentan las características de un mercado casi monopólico (Mera, 2009; USAID, 2009).

El cuarto reto identificado, se relaciona con el crecimiento en la demanda o la posibilidad de llevar la concha a segmentos de consumidores de mayores ingresos, debido a la problemática de la higiene e inocuidad de la concha. Es decir, este reto se asocia a riesgos para la salud, debido a que las conchas viven y se reproducen en estuarios o zonas fangosas donde se acumula el agua que es arrastrada por afluentes desde los asentamientos humanos o explotaciones agrícolas, por lo que están propensas a contaminarse, y considerando que suelen comerse crudas o ligeramente cocidas transmiten al cuerpo receptor las infecciones y enfermedades presentes en ellas (Becerra, s.f; Sandoval & Saborío, 2008 citados en Lazarich, et al. 2009).

[2] La extracción de conchas se le conoce popularmente entre quienes se dedican a ella como conchar, por ello se llama conchero a quien la realiza.

MÉTODOS Y DATOS

La primera parte del estudio se realizó mediante una búsqueda de información secundaria a nivel nacional e internacional sobre la concha *Anadara similis* y *A. tuberculosa*. La información secundaria nacional que se obtuvo, respondía a regulaciones sobre la posibilidad de que la concha sea un excelente vehículo para la transmisión de enfermedades como la Hepatitis B y parásitos como E. coli., lo cual se reflejan las comunidades donde se realiza el concheo.

A nivel internacional, se encontraron trabajos investigativos sobre el hábitat de la concha, algunos sobre las normativas de inocuidad de los moluscos bivalvos para el consumo humano, un estudio sobre cadena de valor de la concha negra en Ecuador e información sobre la veda en Perú. Y en estudios de finales del siglo XX se habla sobre el peligro de estar explotando la concha de manera no sostenible en países como Costa Rica y Nicaragua.

La información secundaría obtenida se complementó con información primaria sobre cantidades, precios, procesos, conocimiento de los actores sobre la regulación existente en la materia, acuerdos y relaciones de coordinación, que se obtuvo mediante la aplicación de una encuesta específicamente diseñada para cada uno de los cuatro niveles de eslabonamientos identificados –puntos de venta al consumo final, meseros, intermediarios y acopios; concheros y proveedores de servicios y productos a los concheros. Para el diseño de la encuesta se consideró la propuesta del M4P y las sugerencias obtenidas en julio de 2012 en el Workshop realizado en Zanzíbar por el Programa CRSP y la Universidad de Hawaii.

Para obtener esta información se hizo un rastreo de los actores, empezando por aquellos que venden los productos ya procesados al consumidor final hasta el extractor en las comunidades; es decir que el punto de entrada seleccionado fueron los puntos de venta al consumidor final. Aunque también se decidió agregar como punto de venta al consumidor final a los meseros[3] de los mercados; si bien estos actores no procesan la concha, si venden al consumidor que desea prepararlas por sí mismo.

Una vez, identificado el punto de entrada, lo siguiente fue determinar la muestra, pero considerando que no hay un censo de bares, restaurantes y coctelerías y menos especializado en los que vendan conchas, se utilizó el registro de las páginas amarillas actualizado al 2012 para determinar las ciudades con mayor número agregado de puntos de venta de alimentos y bebidas preparados al consumo final –bares, restaurantes y coctelerías. Las ciudades seleccionadas de acuerdo a este criterio fueron: Managua, Chinandega, León, Masaya, Granada, San Juan del Sur y Estelí. No obstante, se decidió agregar las siguientes ciudades: El Viejo, Paso Caballo y Corinto, en Chinandega; y Poneloya y las Peñitas en León, por su proximidad a los sitios de extracción de la concha y a las playas de Chinandega y León.

[3] El término “mesero” o “mesera” se utiliza para referirse a la persona que vende en los mercados; deriva del hecho de que los productos los exhiben sobre las mesas.

Tabla No. 1: *Encuestados en cada eslabón y el sitio donde se realizó la encuesta*

Eslabones	N=313	Ubicación
Servicios y productos (n=18)	1 Venta de combustible 6 Dueños de botes 1 Taller de carpintería 2 Talleres de costura 3 Venta de materias para pesca 5 Pulperías	**León**: Salinas Grandes. **Chinandega**: El Realejo, Aserradores, Isla Maderas Negras, Isla Venecia, Posa de la Vaca, El Playón y Chinandega.
Extracción (n=121)	121 Concheros, de los cuales 12 son miembros de la cooperativa Julia Lara en El Rosario, Chinandega	**León**: Poneloya, Salinas Grandes y Barrio Nuevo. **Chinandega**: El Realejo, Paso Caballo, Alemania Federal, Corinto, El Playón, Angara, El Realejo Sur, El Rosario, Aserradores, Isla Venecia, Isla Maderas Negras, Padre Ramos, Posa de la Vaca, Teodoro King, El Zapote y El Viejo.
Intermediación (n=83)	18 Acopiadores 29 Intermediarios 36 Meseros	**Chinandega**: Chinandega, El Viejo, Corinto y El Realejo. **León**: León; **Estelí**: Estelí; **Masaya**: Masaya; **Granada**: Granada.
Procesamiento y Comercialización (n=91)	19 Bares 52 Restaurantes 16 Coctelerías 2 Vendedores ambulantes 1 Discoteque 1 Marisquería	Managua: Managua; Masaya: Masaya y Catarina; Estelí: Estelí; Granada: Granada; Rivas: Rivas y San Juan del Sur; Carazo: Jinotepe; León: León y Poneloya; Chinandega: Chinandega, Corinto y El realejo.

Fuente: Elaboración propia

El número de BRC (bares, restaurantes y coctelerías) en cada ciudad no fue determinado a través de una formula. Es decir no se determinó una muestra, sino que se procedió a visitar cada BRC en cada una de las ciudades y si este vendía conchas se aplicaba el instrumento diseñado para obtener la información antes mencionada y datos sobre la persona o grupo de personas a quienes le compra la concha, de manera que se pudiera continuar al nivel precedente. El número total de encuesta fue de 313, con mayor nivel de detalla se puede apreciar en la tabla 1.

A los meseros que venden conchas en los mercados donde compran los BRC se aplicó la sección sobre la compra de la concha negra, de manera que pudiera obtener datos para determinar el siguiente nivel. Aquellos casos donde el BRC o el mesero no brindaron información suficiente para poder identificar a los actores precedentes, fueron eliminados o no considerados en el análisis. El rastreo desde los BRC hasta los concheros permite entender el funcionamiento de la cadena de la concha. De modo que si no se puede tener información de cada uno de los actores, sea que estos tengan acuerdos o lo hagan por medio de relaciones de mercado, no se podría entender el funcionamiento.

Por tanto, todos los concheros encuestados hacia el final de la cadena tenía que haber sido referidos por los BRC, meseros o los intermediarios. En muchos casos, los intermediarios fueron de mucha ayuda para reunir a los concheros o ubicarlos en las comunidades. En el caso de los concheros que venden directamente a los meseros en los mercados, estos fueron encuestados al momento que realizaban la venta. No obstante, se aclara que no se entrevistaron a todas las personas involucradas, sino que se seleccionaron a las tres más importantes –de acuerdo a la cantidad de conchas que se le compra- identificadas por cada nivel precedente.

El análisis de los datos obtenidos de los diferentes actores encuestados, se hizo en el software estadístico SPSS. Las respuestas a las preguntas abiertas fueron cerradas en enunciados cortos y codificadas de manera que se permitiera mayor nivel de análisis. En el caso de las observaciones donde no hubo respuesta, se codificaron como valores perdidos y fueron excluidos.

El mapa de la cadena se construyó considerando el análisis de los flujos de los principales canales de comercialización. Para determinarla importancia y la relación que se dan dentro de la cadena, se utilizó las cantidades de conchas que pasan a través de los diferentes canales hacia el consumidor final.

COMERCIALIZACIÓN DE LA CONCHA NEGRA

La concha negra es extraída en los esteros o las zonas pobladas por manglares, en las costas de los Departamentos de León y Chinandega. En estos departamentos, las zonas de manglares se concentran entre las costas de Salinas Grandes y Poneloya en León; Corinto, El Realejo y El Viejo en Chinandega. En estos municipios los 120 concheros encuestados extraen 22,590 docenas de conchas por semana y entre 105[4] de estos venden 18,777 docenas en el mismo período.

Según estudio realizado por Hernández, N., Saavedra, A & Maradiaga, J. (2011) indican la existencia de 861 concheros en veinte comunidades de los Departamentos de León y Chinandega, con producción anual de 3,001,290.00 docenas de conchas negras.

La extracción de la concha negra es una actividad artesanal. No tiene procesos específicos de transformación a lo largo de ella, sino que el valor se agrega en la etapa final; en los eslabones anteriores, solo se da un proceso de traslado.

Una vez extraída la concha del manglar, entra al proceso de intermediación donde participan tres actores especializados y un grupo de concheros – extractores de concha-. La participación de este grupo de concheros, depende mucho de la distancia entre la localización del consumidor final o los procesadores de segundo nivel. A medida que la distancia incrementa, se reduce la posibilidad de que los concheros lleguen hasta el consumo o los procesadores.

El 83% (18,777 docenas) de las conchas extraídas se venden al consumidor final a través de bares, restaurantes, coctelerías y meseros. El 23% sigue el canal de bares, restaurantes y coctelerías (BRC) y el 77% pasa al consumidor final por medio de los meseros. Los mercados que más vende concha son: Managua (4,090 docenas), Chinandega (3,252), El Realejo (3,060), León (2,405), Masaya (800), El Viejo (600), Corinto (143) y Estelí (20).

Al comparar los flujos semanales de conchas que pasan por los BRC y los meseros en los diferentes municipios, Managua es indiscutiblemente el principal mercado para la venta de la concha, capturando el 32% (6,031 docenas por semana) del total, de los cuales el 32% (1,914 docenas) pasan por los BRC y el restante 68% (4,090 docenas) por los meseros en los mercados (Figura No.1).

Chinandega es el segundo mercado tanto para BRC como meseros. Por medio de los BRC se vende 567 docena, mientras que por los mercados 3,252. El caso de El Realejo es interesante porque mueve 3,060 docenas a pesar de no tener mercado, por lo que es claro que su actividad la realizan en mercados cercanos como el Corinto o los tres mercados de Chinandega (es importante señalar que en esta zona se ubica la mayor venta de cocteles en la playa). Por otro lado, los mapas muestran como a medida que la distancia entre los municipios de concheo y las costas populares para el turismo de playa aumenta, el flujo de concha se va reduciendo.

[4] 15 de los 120 no dieron información sobre las cantidades vendidas.

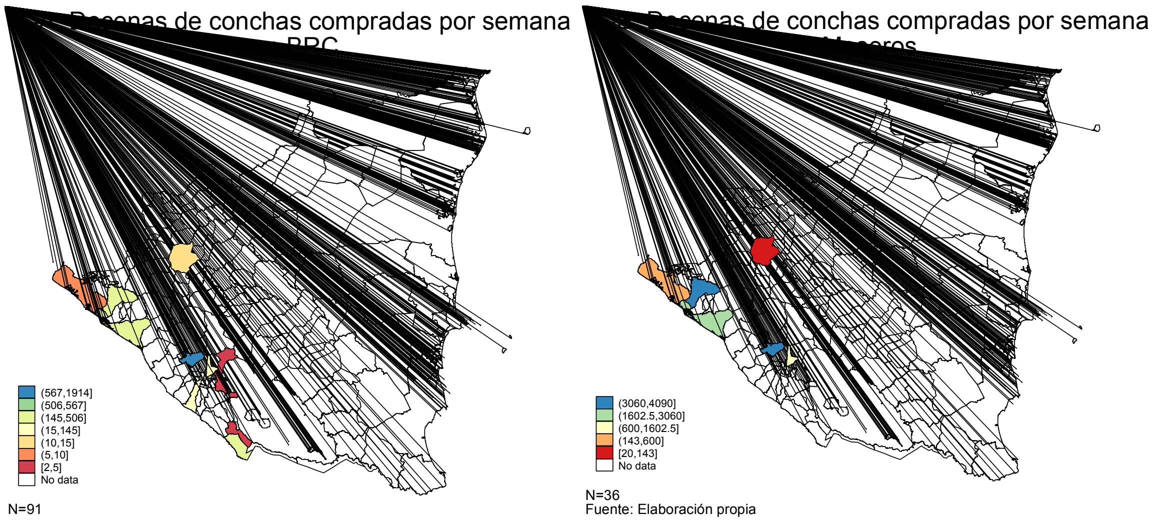
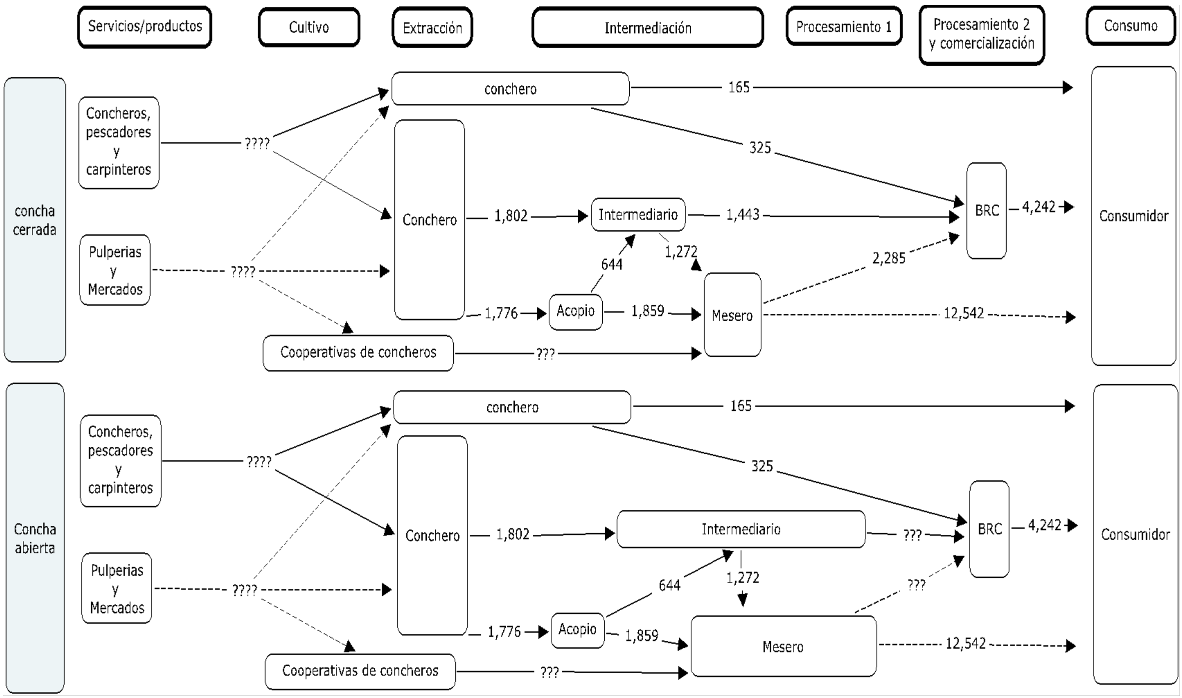


Figura No.1*: Comparación entre docenas de conchas compradas por BRC y Meseros*

La cadena tiene seis procesos previos al consumidor (Figura No.2): servicios y productos necesarios para realizar el concheo, cultivo, extracción, intermediación, primer procesamiento y segundo procesamiento y comercialización. Tres de los cuales cumplen simplemente la función de movilización de la concha sin trasformación alguna.



Fuente: Elaboración propia[5]

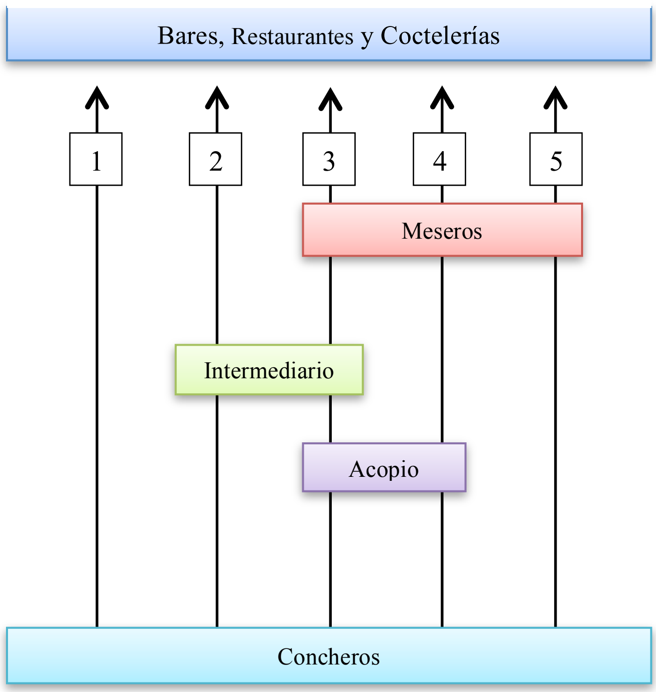
***Figura No.2**: Cadena de la concha negra (flujo de docenas por semana)*

A pesar de que en la Figura No.2 se presentan dos cadenas, concha cerrada y concha abierta que corresponde a los términos usados-por los actores a lo largo de la cadena-, existe únicamente una cadena de valor al no haber diferencias en cuanto a los requisitos de calidad exigidos por los actores del eslabón del segundo procesamiento y comercialización. La separación obedece a una mejor visualización del proceso extracción que se realiza con la concha abierta, no obstante los datos corresponden a la misma cadena, no pudiéndose establecer cuantas docenas corresponde a concha abierta y cerrada.

En la cadena intervienen seis principales canales de comercialización, de los cuales dos van al consumidor directo, los otros 4 pasan por los BRC. El canal más corto es el que va directamente del conchero al consumidor, pero al mismo tiempo es el de menor peso, al comercializar 165 docenas por semana. Es seguido por el canal conchero-BRC-Consumidor con un flujo de aproximadamente 325 docenas por semana; el tercer canal más corto involucra a los conchero-mesero-consumidor con un flujo aproximado de 12,542 docenas por semana.

Los canales que pasan por los BRC se observan más claramente en la Figura No.3, donde se han codificado siguiendo el mismo orden de la Figura No.2. Entre los concheros y los BRC intervienen tres niveles de intermediación, los acopios, intermediarios y los meseros. Los niveles se identifican más claramente a medida que crece la distancia entre la comunidad del conchero y el mercado final.

[5] Nota: los datos sobre las cantidades que entran y salen de cada nodo no son iguales por la pérdida de conchas, no se han representado todas las interacciones entre los actores y se han tomado los 5 principales.



Fuente: Elaboración propia

Figura No.3: *Canales de comercialización que pasan por BRC*

De manera que en el primer canal, los concheros que vende a los BRC son aquellos que viven en las playas de Poneloya, Corinto, Alemania Federal, Paso Caballo y El Realejo. En el segundo, tercer y cuarto canal, la distancia hace necesario la presencia de otros actores con mayor capacidad financiera para poder comprar y trasladar la concha a mercados más alejados, como Managua, Masaya, Granada, Rivas, Jinotepe, Estelí y San Juan del Sur.

El canal 5, es interesante por cuanto acá solo pueden participar aquellos concheros que tienen como vecino a un mesero al que le venden por la tarde las conchas que extraen en el día y que luego el mesero llevará al mercado. Estos meseros diversificados tienen como características que las conchas es algo complementario, en una gama de productos que ofrecen al consumidor.

El otro tipo de conchero que participa en este canal, es aquel que se dedica al cultivo de la concha y que por tanto, cuenta con permiso del Ministerio del Ambiente y Recursos Naturales (MARENA) para trasladar la concha dentro del territorio nacional. Para poder llegar directamente a los BRC, este tipo de conchero ha enfrentado dos restricciones:

1. Dificultad al iniciar relaciones con BRC debido a que ya tienen un proveedor.
2. Baja capacidad financiera para absorber los costos de intermediación.

Un ejemplo de ello, ocurrió con la cooperativa de mujeres concheras de El Rosario, que dejaron de vender conchas tres meses antes de que se visitara la comunidad. Al inicio, un familiar de un miembro de la cooperativa que vivía en Mangua, recibía las conchas en ésta ciudad cada semana. Después de un tiempo esta relación se terminó debido a los altos costos de transporte de El Rosario a Chinandega, estos podían ser de C$150 córdobas.

A partir de esto, la cooperativa empezó a vender conchas a los meseros en los mercados de Chinandega. El precio que estaban recibiendo era igual al precio que recibían los concheros que no tienen costos de un vivero[6]. Esto llevó a tomar la decisión de suspender temporalmente la venta de concha.

PRECIOS QUE RECIBEN LOS BRC

En la tabla No. 2, se observa que el precio de compra de la concha depende de la calidad del producto a la hora de entrega y el tipo de especie. Tiene mejor precio las docenas de conchas mixtas, *similis* (macho) y *tuberculosa* (hembra) combinadas en la misma docena.

En relación a las especies, la *tuberculosa* es más cara que la concha *similis* en los restaurantes y coctelerías. Extrañamente, la concha cerrada y limpia independientemente de su especie, tiene un precio menor que la concha cerrada y sucia sin importar el eslabón.

Tabla No. 2: *Precios medios que pagan los BRC*[7]

Precio que pagan los BRC por la concha (Córdobas)			
Tipo de concha	Bar	Restaurante	Coctelerías
Hembra CyS*	18	16	
Hembra CyL**	14	14	
Hembra abierta			26
Macho CyS		20	18
Macho CyL		9	
Macho abierta			18
Mixta CyS	18	18	19
Mixta CyL		25	14
Mixta abierta	20	22	26

*CyS: cerrada y sucia; **CyL: Cerrada y limpia
Fuente: Elaboración propia

Al comparar los precios de la tabla No.2 con la tabla No.3 demuestran que si los BRC comprarán la concha *tuberculosa* cerrada y sucia, directamente al conchero se ahorrarían de C$3 a C$6 córdobas y al menos C$1 en la concha hembra cerrada y limpia; C$ 15 en la concha macho cerrada y sucia; y entre C$7 y C$11 en la concha mixta.

Al comparar los precios a través de los distintos canales, tanto los que van directamente al consumidor como los que pasan por intermediarios o procesadores, el ganador es el intermediario, que compra la concha a un precio entre 4 y 12 córdobas directamente del conchero y vende a precios entre 14 y 26 córdobas la docena. El otro ganador es el mesero, que suele comprar a precios entre 10 y 12 y vende a precios similares que el intermediario. En cambio el acopiador, recibe un 1 córdoba de diferencia entre el precio al que compra al conchero y al que vende al intermediario. En sí, el acopiador lo que hace es bajar los precios al conchero para poder ganar un córdoba al vender al mismo precio que lo haría el conchero (ver tabla No.3).

[6] Se extraen juveniles del medio natural y de ponen en espacios rodeados de malla monofilamento en el manglar
[7] Tipo de cambio oficial a final de diciembre 2012: 24.1265 córdobas por un dólar americano.

Tabla No.3*: Precio medio al que el conchero vende la concha por tipo de comprador*

	Precio medio al que el conchero vende la concha a sus compradores (córdabas)					
Tipo de concha	Acopio	Intermediario	Mesero	Consumidor	BRC	Conchero
Hembra CyS*	9	9	10		13	10
Hembra CyL**	9	9	10			8
Hembra abierta***			20			
Macho CyS	4	4			5	7
Macho CyL	4	5				8
Mixta CyS	9	10	12	10		12
Mixta CyL	9				11	10
Mixta abierta					12	

* cerrada y sucia; **cerrada y limpia
Fuente: Elaboración propia

CARACTERIZACIÓN DE LOS ACTORES POR ESLABONES

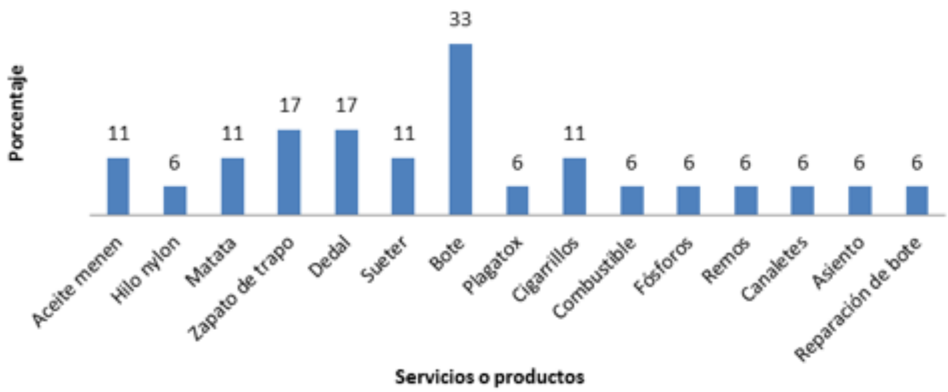
Servicios y productos para el conchero

El primer eslabón se llama servicios y productos y no insumos porque no cumplen con la condición de brindar productos que se integren al producto que los concheros luego venden a los siguientes eslabones, sino que proveen servicios y productos que son necesarios para realizar el concheo. En este eslabón participan algunos concheros, las pulperías, carpinteros y pescadores de las comunidades donde se conchea y puestos de venta en los mercados cercanos a las comunidades.

Los proveedores de estos servicios y productos fueron encuestados en las comunidades de Salinas Grandes, León; El Realejo, Aserradores, Isla Maderas Negras, Isla Venecia, Posa de la Vaca, El Playón, Chinandega; y la ciudad de Chinandega. De estos proveedores 13 se encuentran en zonas rurales y solo 5 están en las ciudades, 10 son hombres y 8 mujeres, con edades comprendidas entre los 27 y los 60 años, con una edad media de 39 años.

El 50% (nueve) de los proveedores alcanzó algún grado primaria, de los cuales el 55% concluyó la primara; el 22% estudio la secundaria, pero nadie la completo y una persona fue a la universidad y la termino; mientras que un 22% (4) no asistió a ningún nivel de educación formal. Estos datos revelan que lo primordial en zonas rurales es la búsqueda de una estrategia de vida restando importancia a la educación y especialización.

Existe una alta rotación de proveedores. El 72% (13) de los negocios son relativamente nuevos, tiene menos de 4 años de estar operando. El 88% (16) de los negocios no están registrados en la Alcaldía, lo que es razonable considerando que 13 están ubicados en zonas remotas; lo que significa que 3 de los 5 negocios del área urbana aún no se han legalizado. El 33% son propietarios de un bote que lo utilizan para pescar, transportar leña y rentarlos debido a la presencia de concheros. El costo de alquiler no supera los C$30 córdobas por día. El 28% son dueños de pulperías y venden gran cantidad de los productos que el conchero utiliza (Figura No.4).



Fuente: Elaboración propia

Figura No.4. *Servicios y productos que utiliza el conchero*

Los concheros que participan en este eslabón, son aquellos que han tomado la oportunidad para diversificar sus ingresos aprovechando su experiencia en la elaboración de las matatas, los dedales y los zapatos de tela (trapo), tienen un pequeño mercado en los concheros nuevos que no tienen la experiencia para elaborarlos o en aquellos que simplemente prefieren comprarlos hechos.

Por la ubicación de las zonas de concheo, las pulperías al igual que los propietarios de botes son importantes para los concheros en las comunidades. Las pulperías están bien abastecidas permitiéndoles acceder rápidamente y sin incurrir en el costo del transporte a los productos que necesitan cada vez que van a extraer conchas. En el caso de los botes les permite a los concheros poder movilizarse a lugares más alejados en busca de mejores bancos de conchas.

Cultivo

En este eslabón solo hay un actor, las cooperativas de concheros, la cuales tiene en administración un área de mangle determinada por el MARENA y la Alcaldía[8]. Dentro de sus responsabilidades está elaborar un plan de manejo con participación de las comunidades, que luego debe ser revisado y aprobado por el MARENA.

Las personas que se dedican al cultivo de la concha tiene que cumplir con los siguientes requisitos establecidos en 2008 por MARENA en la resolución ministerial N° 028-2008:

- Los viveros para el cultivo de la concha debe estar rodeados por una malla sarán 40% sombra y tendrán una dimensión de 30 x 40 ms, con entierre de 20 cm, para asegurar el almacenamiento de 120 mil conchas anuales
- Extraerán concha de otros puntos del estero hacia el vivero en tanques bidones de 30 litros o en sacos de polietileno.
- Deben garantizar una salinidad entre 25 a 35% , una temperatura entre 19 a 30 grados Celsius y un pH entre 6.4 a 9
- Debe garantizar una densidad de 100 conchas por metro cuadrado y sembrar 10 mil conchas cada 30 días
- Llevar los siguientes controles:
  - Cantidad introducidas al vivero por talla y peso
  - Realizar medidas cada 15 días
  - Número de conchas extraídas por mes por persona
- Además el vivero debe contar con la siguiente infraestructura:
  - Senderos suspendidos y espacio techado para la vigilancia

La única experiencia de este tipo que se pudo observar, está ubicada en la comunidad de El Rosario. Es una cooperativa formada por 12 mujeres, quienes recibieron de MARENA capacitaciones para cumplir con las normativas y dar mantenimiento al vivero. El estar organizados les trae como beneficio el tener permiso para vender la concha libremente en el mercado nacional, siempre que la concha mida 5 cm o más.

Al inicio del cultivo los costos de construcción del vivero fueron cubiertos por el MARENA. Mientras que los costos de mantenimiento deben correr por la cooperativa, la cual debe garantizar obtener ingresos por venta de concha que le permita tener un margen de ganancia sobre los costos de mantenimiento para hacer rentable la actividad.

El costo de mantenimiento más recurrente es la reposición de la madera de los senderos y los mojones que sostienen la malla. Podría pensarse que no es algo complicado ni costoso debido a que la comunidad se encuentra en las faldas del Volcán Cosigüina, sin embargo, hay que considerar que el Volcán forma parte de la reserva natural del mismo nombre y por tanto, la extracción de madera es restringida. De modo que la simple reposición de la madera es un costo que debe ser asumido.

[8] ***Para más detalle ver la regulación formal en la sección de gobernanza***.

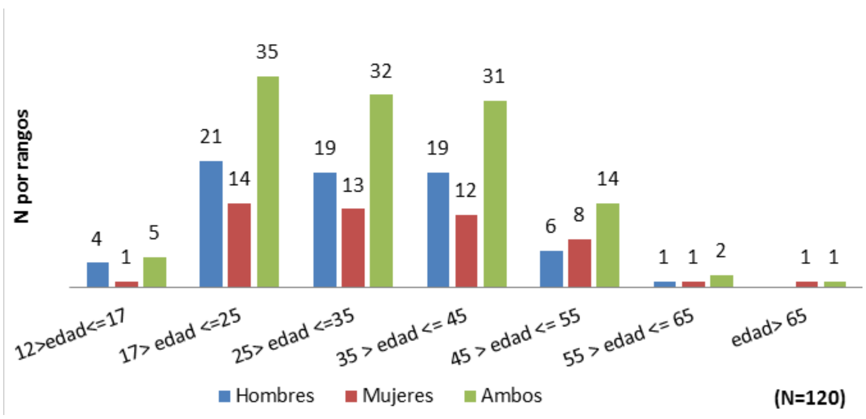
Sin embargo, en el Diagnóstico Concheros realizado por Hernández, N., et al (2011), también indican la existencia de la Cooperativa de Servicios Múltiples de pescado Artesanales del Pacífico Cooperativa 1 de septiembre en Poneloya en León y la Cooperativa Asociación de Trabajadores del Mar (ATEMAF) en Alemania Federal, El Realejo, Chinandega que cuentan con área concesionadas para el cultivo de conchas negras.

Extracción

La extracción la pueden realizar tanto concheros en cooperativas como individuales. Según la resolución ministerial N° 028-2008, ambos deberían solicitar permiso al MARENA para poder extraer la concha. No obstante, los concheros independientes y los intermediarios, dicen que en la práctica los permisos los otorga la Alcaldía y que son solo para las cooperativas o intermediarios.

A pesar de que hay dos tipos de concheros por la forma de organización, las personas que se dedican a esta actividad tienen características y actividades comunes por lo que en esta parte se hablará de esas características sin considerar si las personas están organizadas en cooperativas o no.

En las comunidades donde se realizaron encuestas a concheros, el 59% (71) de las personas dedicadas al conchero son hombres con edades mayormente comprendidas entre los 18 a 45 años. En cambio las (51) mujeres tienen edades entre los 18 a 55 años(Figura No.5).



Fuente: Elaboración propia

Figura No.5. *Rango de edad de los concheros*

Tanto hombres como mujeres inician en el concheo a una edad entre los 12 y 17 años, con mayor participación de hombres. Los hombre participan más en el concheo que las mujeres hasta alcanzar los 45 años, a partir de este momento, las mujeres son quienes más participan. Más allá de los 65 años solo las mujeres se dedican al concheo, mientras que los hombres dejan de conchar al alcanzar está edad.

Considerando que hay al menos una persona que tiene 50 años de ser conchero, la mayoría de las personas encuestadas tienen relativamente poco tiempo, ya que 79 de 119 se encuentra entre los rangos de meses de 13 a 240 meses – de dos años a diez de ser conchero (tabla No.4).

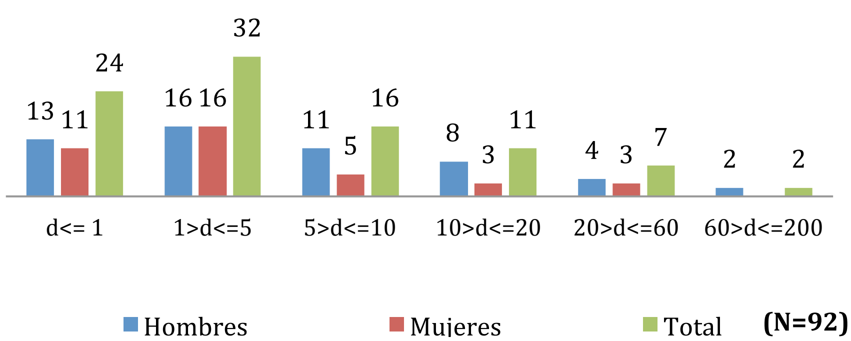
El 40% de las personas dedicadas al concheo no tienen educación formal, el 50% estudio la primaria, donde el promedio de años estudiados es de 4, es decir, primaria incompleta. El 10% que estudio la secundaría, aprobó el 3 año, por lo que en promedio tampoco terminaron la secundaria.

Tabla No.4: Tiempo de conchar por sexo del recolector

Rango en meses	Sexo del recolector		Total
	Masculino	Femenino	
t<= 12	6	1	7
12 > t <=120	24	17	41
120 > t <=240	23	15	38
240 > t <= 360	9	9	18
360 > t <= 480	5	6	11
480 > t <= 600	3	1	4
Total	70	49	119

Fuente: Elaboración propia

Debido a que no todos los sitios de concheo se encuentran en la comunidad donde viven los concheros, la mayoría de las personas viajan entre mil y cinco mil metros para llegar al sitio. La mayoría de las mujeres (27) recorren distancias comprendidas entre menos 1 a 5 Km, con una distancia mayor recorrida de 60 mil metros. Mientras que los hombres recorren hasta 200 Km (Figura No.6).



Fuente: Elaboración propia

Figura No.6 *Distancia en metros al banco de conchas*

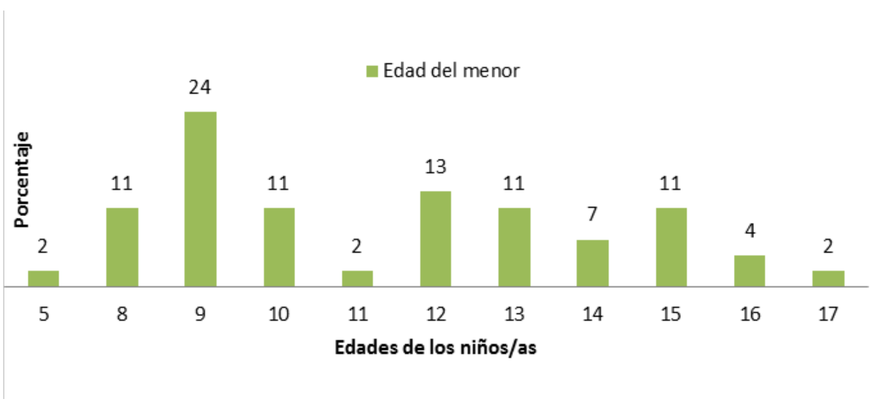
En la tabla No.5 se puede ver que hay personas de León que van a conchar a Corinto, El Realejo; de Corinto van a Poneloya, de El Realejo van a Isla Venecia que está en el Estero de Padre Ramos y de El Viejo van a los municipios de Corinto y El Realejo; lo cual explica las distancias recorridas. Po otro lado, la tabla permite ver que los concheros de Corinto y El viejo son los que más bancos de conchas explotan dentro o fuera del municipio. Y son los de Corinto y El Realejo los que mayor distancia recorren para ir a conchar, ya que van hasta Poneloya y Salinas Grandes, en el Municipio de León.

***Tabla No.5**: Sitios donde se conchea por municipio donde vive el conchero*

Municipio donde vive el conchero y sitio de concheo (N=121)				
Sitios de concheo	León	El Realejo	Corinto	El Viejo
	Corinto	El Realejo	El Realejo	Aserradores
	Poneloya	Corinto	Corinto	El Realejo
	Puerto Sandino	Paso Caballo	Paso Caballo	Corinto
	Salinas Grandes	Alemania Federal	Poneloya	Padre Ramos
	Los Braciles	Poneloya	Salinas Grandes	Maderas Negras
	La Palma	Isla Venecia	Isla Venecia	El Viejo
		El Barquito	El Barquito	Posa de la Vaca
		Punta Gorda	Jicarillo	El Rosario
		El Limón	El Ranchito	Jiquilillo
			El Panteón	Castepe
			Monte Ralo	Sandillera
				La Toyosa
				Cojollo
				La Caleta
				La Ceiba

Fuente: Elaboración propia

El concheo es una actividad que se realiza en compañía de pocos miembros de la familia. De las 87 personas que son acompañadas por algún miembro de su familia; el 33% de los hombres y el 56% de las mujeres van con un familiar, menos del 30% de los hombres y del 15% de las mujeres van con 3 miembros y menos del 6% para ambos sexos lo hacen con más de 4. El 38% va con el hermano, el 30% con el hijo o el primo y las otras relaciones son tales como: esposa, esposo, hijo, hija, padre, madre, tío, tía, cuñado, cuñada y nieto. En todos los casos se conchea más en compañía de un hombre de la familia.

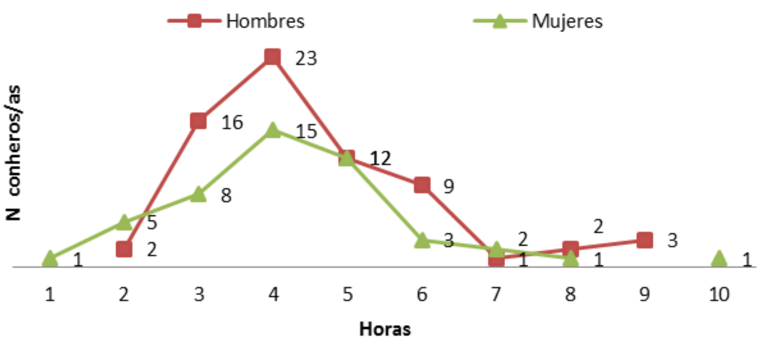


Fuente: elaboración propia

***Figura No.7**. Edad de los menores que acompañan a los concheros*

En el caso de que el acompañante sea un menor de edad, los concheros van con un número no mayor de 4 niños y suelen ser más hombres. Ambos, niños y niñas, pueden empezar a conchar desde los 5 años como se aprecia en el gráfico 4, concentrándose la edad hacia los 9 años (11 de 45 niños). A partir de esta edad el número de niños que acompañan a los concheros disminuye, considerando la Figura No.5, parece ser que los 12 años es la edad en que los jóvenes concheros se independizan su extracción de conchas de las de sus padres.

En cuanto a las horas dedicadas al concheo por día, Figura No.8. Tanto hombres como mujeres tienden a concentrarse entre las 3 y 6 horas por día. Pero hay quienes dedican hasta un máximo de 10 horas por día. Mientras que los menores de edad suelen conchar por el mismo lapso que los mayores, pero ninguno supera las 6 horas al día, a diferencia de los mayores de edad.

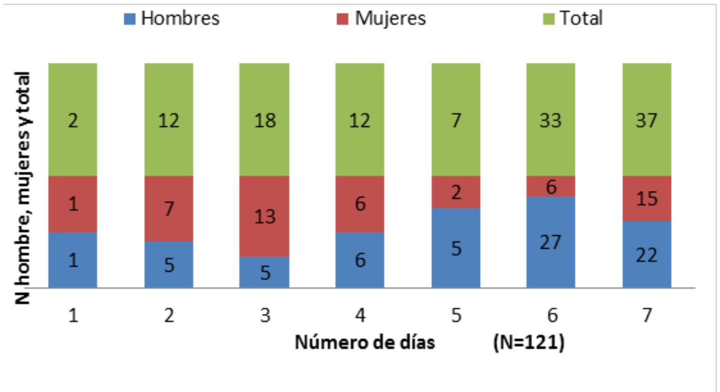


Fuente: Elaboración propia

Figura No.8. *Horas que dedican al concheo por sexo del recolector*

Los días de concheo no depende de la voluntad de la persona, sino de la marea, cuando la marea alta se da durante las horas del día no permite el concheo, ya que estas, según sea la especie se encuentran sumergidas en los fondos blandos abiertos o debajo de las raíces de *Rizophora mangle* de la zona sublitoral entre los 5 a 50 cm de profundidad (E. Mora y J. Moreno. 2006 citado por Hernández. 2012) en dependencia de la especie. A pesar de esto, según se observa en la Figura No.9. un cercano 60% de concheros desarrolla la actividad por más de cinco días en la semana, lo que puede significar que viven en zonas aledañas al manglar permitiéndoles mover las horas de concheo según los movimientos mareales.

La A. tuberculosa se ubica dentro del fango de tipo limo arcilloso por debajo de las raíces de *Rizophora mangle* entre 5 y 30 cm de profundidad y A. Similis sobre fondos blandos de la zona sublitoral, entre 15 y 50 cm de profundidad y en espacios abiertos (Mengel y Kirby 1982; Mora 1990; Fisher et all 1995: Borda y Cruz 2004, tomado de E. Mora y J. Moreno. 2006. Citado por Hernández, N. et al. 2012).

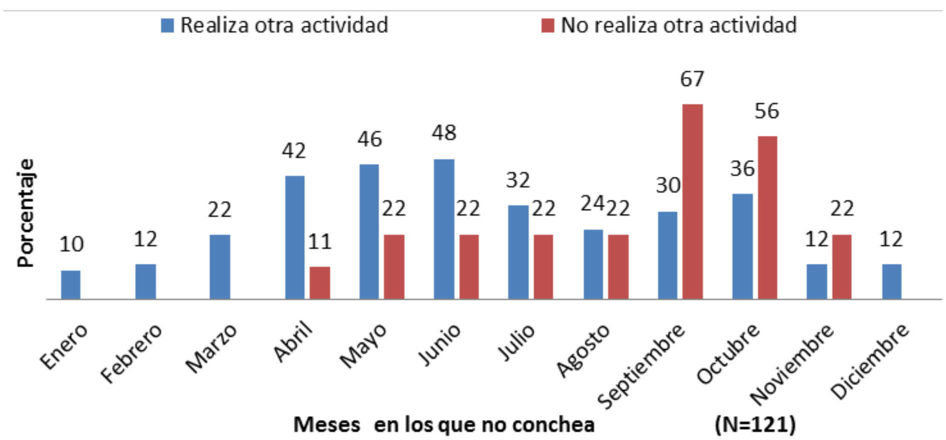


Fuente: Elaboración propia

Figura No.9. *. Dás a la semana que conchean*

En promedio los hombres conchean 6 días a la semana, lo que significaque podrían realizar esta activadad 10 meses en el año; en cambio las muejeres, que en promedio conchean 5 días a la semanas, lo haríán9 meses al año. El 49% de los encuestados (59) no conchea en algun mes del año,estodepende de cada persona, no habiendo un mes específico para dejar de conchar;sin embargo, como se observa en la Figura No.10 los meses que más pesonas dejan de conchar comprendenabril a junio y septiembre a octubre.

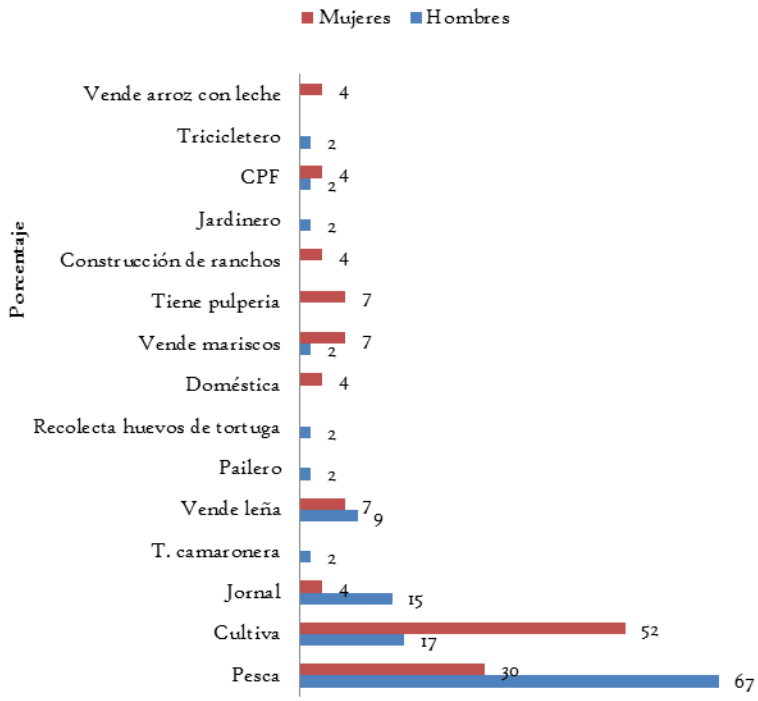
El primer período de meses comprende casi en su totalidad los meses de veda impustos por MARENA y el segundo los meses en los cuales la concha tiene menor precio en el año. Las personas que tiene otra actividad son quienes principalmente dejan de conchar entre abril a junio; mientras, quienes son exclusivamente concheros dejan esta actividadde septiembre a octubre.



Fuente: Elaboración propia

Figura No.10. *Realiza otra actividad cuando no va a sacar conchas*

La salida o entrada de concheros durante el año se debe a la diversificacion de actividades paralelas al concheo y del ciclo en el precio de la concha negra. Las tres actividades que más se realizan como alternativa al concheo son: la pesca (de abril a octubre), la agricultura (de julio a octubre) y la venta de leña (de abril a julio). Además el trabajo como jornaleroes otra actividad a la que se dican los concheros por temporadas (Figura No.11).



Fuente: Elaboración propia

Figura No.11. *Actividades que realiza además de sacar conchas*

En cuanto a la venta de la concha, el 41% vende a intermedirios, 28% a acopios, 8% a bares, restaurantres y coctelerias y un 4% a meseros. Para la comercializacion de la concha,el conchero tiene quetrasladarla hacia el comprador. En este sentido se lleva la concha más a los bares, restaurantes y coctelerías, seguido de los mercados y al intermediario fuera de la comunidad. Mientras, que más de un 25% vende la concha tanto en acopios o al intermediario de la comunidad–no en todas las comunidades hay intermediarios. Los compradores se ubican principalmente en Corinto y El Realejo, donde se encuentran tres de los intermediarios más grandes.

El tipo de concha de mayor demanda,varía de acuerdo a la cantidad de docenas. Por ejemplo, la concha *similis* se vende más que la *tuberculosa* o que la combinación de ambas (similis y tuberculosa) en un rango no mayor a 15 docenas, mientras que en los rangos que van de16 a 70 docenas se vende más la combinación de ambas conchas.

El proceso del concheo requiere poca inversión en tecnología, solo necesita de ir a los estuarios y extraer la concha manualmente durante un período de 2 a 6 horas al día, despues es vendida sin ningún valor agregado. Un 3% de los concheros vende la concha abierta o limpia –remueve el lodo con el que la concha es extraída por solicitud del comprador, de lo contrario la vende cerrada y sucia –con lodo.

De los productos que utilizan, la mayoría son para alejar los mosquitos y proteger sus brasos y pies de las raices del mangle. La matata sirve únicamente para el almacenamiento temporal y traslado de la concha, pero no es indispensable ya que puede ser sustituida por sacos o mochilas.

Intermediación

En este nivel existe tres actores, los intermediarios, acopiadores y los meseros. Por los datos de venta de los concheros, se sabe que el principal en el canal de distribucion es el intermediario que puede vivir en la comunidad del conchero o fuera.

Los actores en este nivel son en un 52% personas en edades de 36 a 55 años, con una mayor presencia de mujeres. Tienen un nivel de educación mayor al de los concheros, el 28% aprobó 5 años de educación primaria, el 24% cuenta con 4 años de educación secundaria, el 18% tiene un técnico medio, el 30% alguna carrera universitaria y el 18% no realizó ningun año de educación. Independientemente del sexo del propietario los negocios tienen en su mayoria entre 1 a 10 años.

Hace unos diez años, la concha tenía mejor precio y era un negocio más dinámico porque venían compradores de El Salvador, según una intermediaria que antes operaba como acopiadora. Por otro lado, un acopiador e intermediario de Kilaka que vendía conchas en El Salvador, Honduras y Guatemala, considera que la concha tiene buen precio en estos países, principalmente en Guatemala y El Salvador, donde la concha puede llegar a costar más de $1 por docena. Este acopiador dejo de vender conchas en estos países porque sufrió varios decomisos por parte del MARENA y el Ejército, quienes se encargan de ejecutar la veda. En cambio, relató que las autoridades de El Salvador, le brindaron ayuda para obtener permisos para vender la concha en la Unión, donde la concha tiene buen mercado.

Acopiadores

Por la distancia de las comunidades donde se conchea, el acopiador suele ser una persona de la comunidad que también puede dedicarse al concheo y puede o no ser familiar del intermediario. El acopio es la casa, no cuentan con un lugar independiente para mantener la conchas. De los 18 acopiadores, solo 5 operan con permiso de la Alcaldia. Tienen como principal función comprar las conchas en las comunidades donde no hay intermediarios. En dependencia del acuerdo que tengan con el intermediario, entregaran la concha con la frecuencia pactada que en general es cada dos días.

Las personas dedicadas a acopiar generalmente compran y vende la concha en la misma comunidad, en muy pocos casos viajan a ciudades como Managua o La Paz Centro para entregar la concha, por lo que en algunos casos el intermediario llega a la comunidad, pero en otros el acopiador debe ir a entregarla, bien sea en la casa del intermediario o en algún sitio acordado y fuera de la vigilancia del Ejército –junto a la policia son los encargados de ejecutar el control durante el período de veda o en las zonas protegidas, donde se requiere de un plan de manejo para el aprovechamiento de la concha. En general el sitio de entrega depende de que el intermediario tenga o no permiso de la Alcaldía o MARENA para efectuar el traslado de la concha y por supuesto de los recursos financieros para cubrir los costos.

Intermediario

Los intermediariostienen como principales ciudades para la venta de concha León, Chinandega y Managua. Un menor número de ellos vende en ciudades más alejadas como Masaya, San Juan del Sur y Granada. De las 30 personas encuestadas 19 operan en su casa, lo que significa que ellos no van a dejar el producto, sino que esperan a que el comprador llegue; 8 van a dejar producto a los mercados y 2 operan desde un establecimiento comercial. En si, se observa que algunos intermediarios también juegan el papel de acopiador.

De los tres intermediarios más grandes, dos se ubican en El Realejo y uno en Corinto. Los tres mueven casi toda la concha que llega a Managua y las otras ciudades del Pacifico Sur. Según los intermediarios de

El Realejoque operan legalmente, el permiso de la Alcaldía tiene un costo de C$150 córdobas mensuales más el pago de un canón semanal por el permiso de intermediar un máximo de 1,200 docenas por semana[9]. Con dicho permisopueden desplazarse hasta Managua, pero debido a que después de Managua la regulación es casi inexistente ellos viajan a otras ciudades.

Los intermediarios hombres compra a número máximo de 10 personas, con una mayor presencia de acopiadores entre sus proveedores; en el caso de las intermediariascompran hasta a 16 personas y compran más a concheros.

Como se observa en el diagrama de la cadena, los intermediarios tienen la función de enlazar principalmente el flujo de conchas que va desde los concheros a los meseros y los BRC, pero además, tiene como función hacer efectivo el flujo de conchas y de conocimientos a lo largo de la cadena[10], son los que transmiten hacia los niveles de la izquierda de la cadena, los requisitos de los BRC.

Meseros

De los 36 meseros encuestados el 98% tiene permiso de la alcaldía para operar, de estos el 97% trabaja en los mercados y el restante 3% en la vía pública, es decir, vende en un puesto ubicado en la acera. Dentro de los meseros, los hombres compran la concha a un máximo de 8 personas, en cambio las mujeres no pasan de tres.

A pesar del reducido número de proveedores a los meseros, estos no cuentan con acuerdos. Su relación es comercial, esta definida por la cantidad de conchas que ellos –los meseros- pueden vender por día o semana y a la distancia entre el sitio de origen de la concha y los mercados. En León y Chinandega los meseros compran al primero que llegue, en cambio en Managua y Masaya, la situación cambia, dada la restricción de que no todos los intermediarios pueden viajar a estas ciudades, por tanto, es común encontrar que cada mesero tiene un proveedor con el que han trabajado por años, pero a pesar del tiempo no tienen acuerdos verbales ni tácitos.

Por los acuerdos que los intermediarios tienen con los BRC, se observa que primero visitan a los BRC y luego van a los mercados. Lo que puede significar que la concha que no pueden vender en los BRC la venden en los mercados.

Primer procesamiento

En este nivel participan intermediarios y meseros, ambos venden la concha sin la estructura ósea, es decir, solo venden la carne de la concha acompañada de su sangre. Los intermediarios participan en este nivel debido a los acuerdos que tengan con los BRC de entregar la concha ya abierta. Mientras que los meseros, suelen participar de este nivel cuando no tiene concha abierta -generalmente el mesero le pide al intermediario cierta cantidad de conchas abiertas, por tanto su participación es eventual.

De manera que los intermediarios lo hacen porque ya tienen arreglos establecidos y los meseros lo hacen bajo solicitud de los consumidores que ahora prefieren llevar la concha lista para prepararlas.

[9] No se obtuvo el valor de este canon.
[10] ***Ver la sección de gobernanza.***

Segundo procesamiento y comercialización: Bares, restaurantes y coctelerías

Managua fue el sitio donde se encuesto el mayor número de negocios (23), seguido de León (22), San Juan del Sur (9) y Estelí (1). Estos tres actores (BRC) agregan el valor a la concha con el segundo precesamiento que consisten en abrir la concha y prepararla en varidados platillos; pero también realizan la comercialización en sus establecimientos.

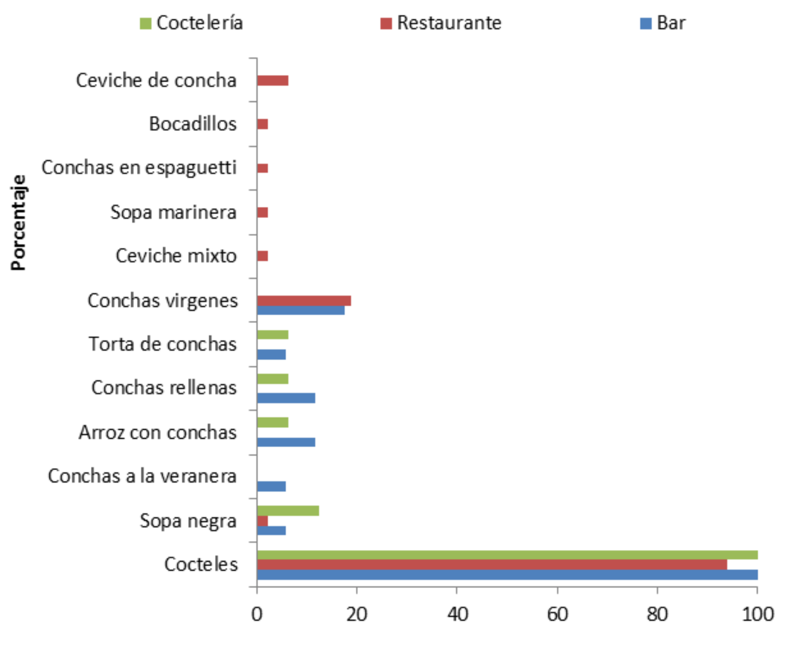
En adelante se utilizará el termino procesadores para referirse a los actores que intervienen en el segundo procesamiento y comercialización. Se omite hablar de comercializadores, ya que después del segundo procesamiento no existe otro eslabón que realice tal proceso, debido a que cada tipo de procesador tiene su propio segmento de mercado y como es característico de los negocios que se dedican a vender alimentos preparados.

De los procesadores, un 24% de los propietarios tiene una carrera universitaria, el 15% un técnico superior y el 13 % tiene un técnico medio, el 45% tiene en promedio 4cuarto años de secundaría y quinto grado de primaria; y sólo un 3% de éstos no estudió. Claramente se puede apreciar que predominan personas que no sacaron ningún grado técnico o profesional. Las personas que han completado una carrera universitaria son propietarios de restaurantes y bares. Los de nivel de secundaria, es más heterogeneo, predominando los dueños de bares, seguidos por duenos de coctelerías.

En relación de género, los procesadores mayoritariamente son mujeres propietarias de los sitios donde se vende la concha negra. De los establecimientos visitados 28 restaurantes, 10 bares y 11 coctelerias son propiedades de mujeres, mientras que los hombres son dueños de 24 restaurantes, 7 bares y 5 coctelerías. En ambos casos la edad más frecuente esta comprendida entre 36 a 55 años. Por otro lado, los negocios dirigidos por hombres tienen entre 1 a 10 años de estar operando; en cambio el de las mujeres entre 1 a 30 años. Esto sugiere que es una actividad iniciada por mujeres.

En relación al tipo de concha, según la especie, el 80% de los procesadores prefieren la concha mixta, es decir, la combinanción de *similis* y *tuberculosa*, un 14% prefieren la *tuberculosa* y sólo un 6% la *similis.* Los volúmenes de conchas compradas por semana y por tipo de especie ubican a la docena mixta y la de tuberculasa como las más demandas, en un rangode 15 a 70 docenas.

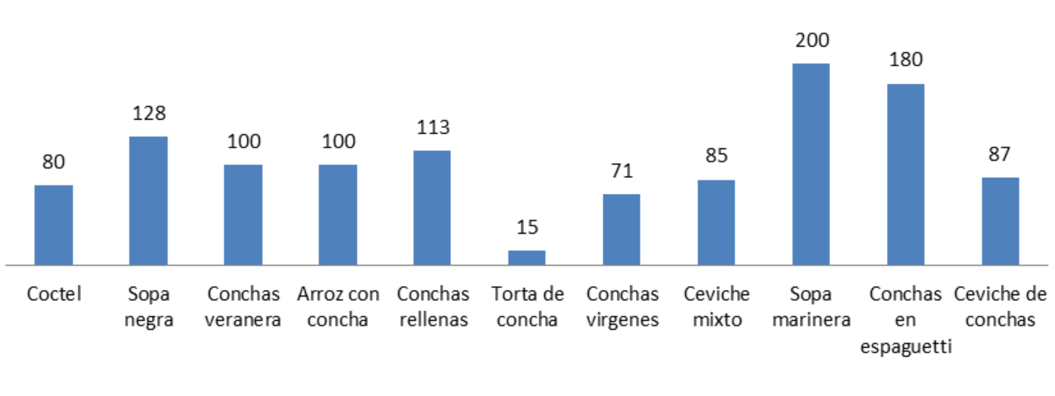
Los procesadores llegan a perder hasta un máximo de 50 docenas de conchas por semana debido a baja demanda, inadecuadas condiciones de manejo de los moluscos vivos y la ausencia de refrigeración del producto, esto último esta directamente relacionada a la cultura del consumo del producto fresco.



Fuente: Elaboración propia

Figura No.12. *Productos preparados a partir de las conchas*

En el procesamiento todos siguen las mismas actividades, que consisten en limpiar la concha, extraer la carne y la sangre para preparar los diferentes platillos a base de concha. La diversidad de platillos depende del tipo de negocio; como se puede ver en la Figura No.12 los bares y coctelerías vende los mismos tipos de platillos, con la característica de que la concha es el elemento principal; en cambio los restaurantes ofrecen platillos donde la concha no es el elemento principal, de ahí su variedad en el uso de la concha y por supuesto la diferencia de precios (Figura No.13).

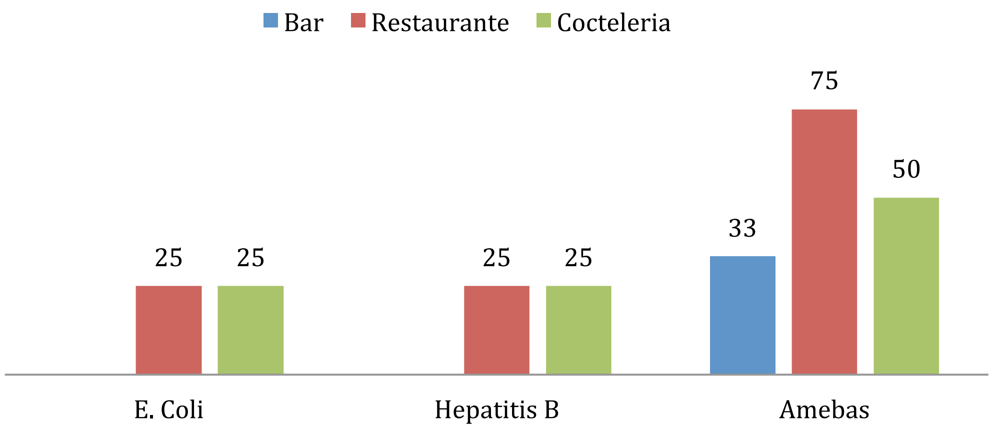


Fuente: Elaboración propia

Figura No.13. *Precio medio de los productos*

Uno de los aspectos que se considera importante para la agregación de valor a la concha es la depuración, de manera que la concha no transmita enfermedades. El 14% de los procesadores saben que la concha puede transmitir enfermedades, de estos el 12% son bares, 11% restaurantes y 25% coctelerías. En la

Figura No.14, se observa que las enfermedades conocidas son: *Echericha coli*, Hepatitis B y Amebas; siendo las amebas la más conocida por todos los procesadores. Por otro lado, son los bares los que menos conocimiento tienen sobre las diversas enfermedades que el consumo de la concha transmite por su nivel de procesamiento[11].



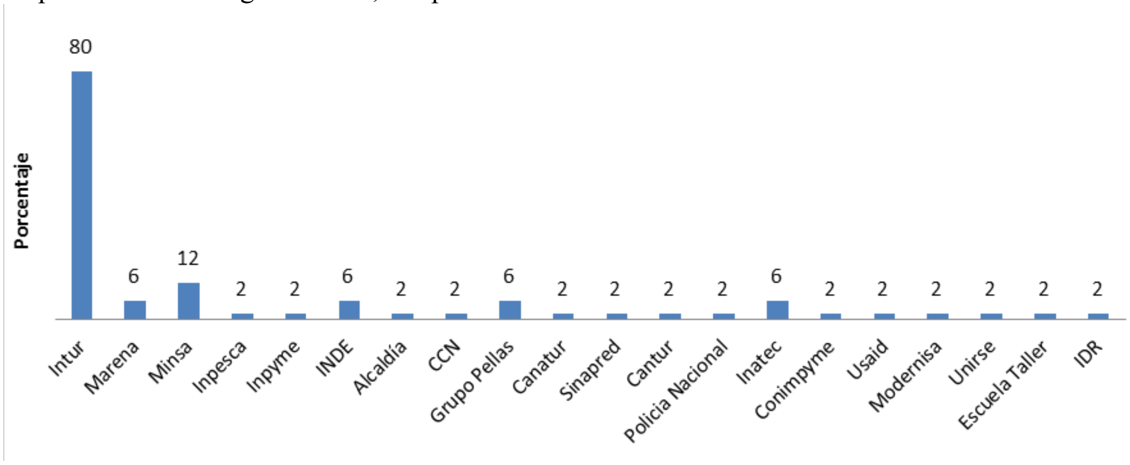
Fuente: Elaboración propia

Figura No.14 *¿Qué enfermedades sabe que puede transmitir la concha?*

[11] ***Recuérdese que la preparación de la concha en los bares y coctelerías no requiere de mayor preparación que agregación de vegetales y limón, por lo que se consume cruda.***

LA GOBERNANZA DE LA CADENA: REGULACIÓN Y COORDINACIÓN

Los actores que se dedican al procesamiento de la concha para comercializarla al consumidor final han recibido capacitaciones de organizaciones que apoyan el desarrollo del turismo, al sector salud, la protección al medio ambiente y recursos naturales, institutos de fomento y apoyo al desarrollo empresarial. En la figura No.15, se aprecia la lista más detallada de estas instituciones.



Fuente: Elaboración propia

Figura No.15. *Organizaciones de las que han recibido asistencia o apoyo los BRC*

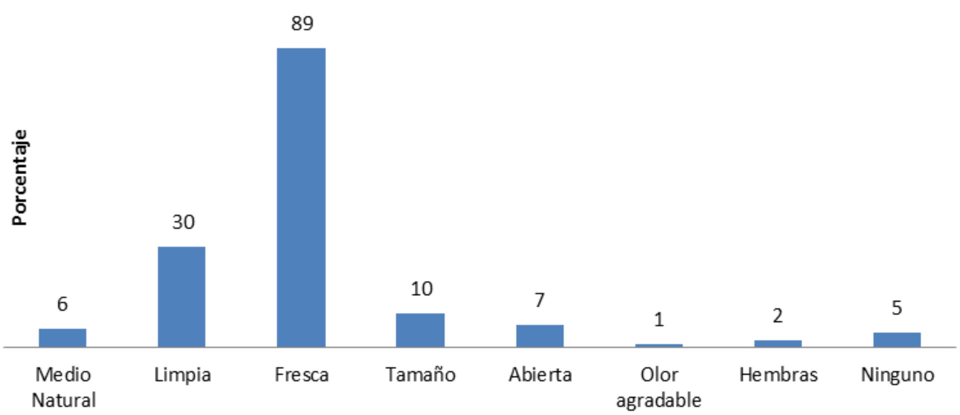
De estas instituciones, el Instituto de Turismo (INTUR) es el que tiene mayor presencia, al haber brindado algún tipo de capacitación al 80%de los establecimientos; seguido por el Ministerio de Salud (MINSA) con el 12% y (MARENA) con 6%.

Las capacitaciones han sido en temas como: manejo y preparación de alimentos, higiene del establecimiento, manejo de mariscos, períodos de veda de todas las especies permitidas para el consumo humano, alimentos nutricionales y reforestación del mangle. Los temas más relacionados con las conchas –veda y reforestación del mangle, la han recibido 5 de 51 establecimientos que dijeron haber tenido algún tipo de asistencia antes de la encuesta.

Estas tres instituciones a través de sus capacitaciones pueden provocar cambios en la forma que la cadena de la concha se coordina para llevar la concha desde el extractor hasta el consumidor final, por medio de la introducción o modificación de normativas sobre la calidad de los productos finales como en el origen. Así como normativas para la conservación y preservación de los recursos naturales. Tanto INTUR como MINSA trabajan la primera parte y la última corresponde más al MARENA.

En el caso particular de la concha, el MARENA a través de las resoluciones ministeriales de veda (1985[12],2004 y 2012), ha establecido que cada año hay un período de veda entre el 21 abril y el 15 de julio. En este tiempo no se permite trasladar la concha de los sitios de explotación hasta los mercados, bares, restaurantes y coctelerías.

En año 2008 MARENA, a través de la resolución ministerial 028-2008 dictó los criterios técnicos para el aprovechamiento de la concha negra que establecieron las tallas mínimas para su comercialización. La concha *A. similis* (macho) debe tener una talla mínima de 4 cm y la concha *A. tuberculosa* (hembra) 5 cm. Las personas que trasladen o comercialicen conchas bajo estas tallas están sujetas al decomiso del producto. En esta misma resolución estableció que las conchas una vez extraídas del mangle deben pasar a refrigeración dentro de las primeras 48 horas. La figura No.16 muestra, los requisitos que solicitan 91 de los 121 los bares, restaurantes y coctelerías (encuestados) al proveedor de las conchas negras.



Fuente: Elaboración propia

Figura No. 16. *Requisitos que deben cumplir las conchas negras para el comprador.*

Se observa como la limpieza y el tamaño son dos de los tres principales requisitos demandado por el comprador. A excepción del tamaño, los otros requisitos son basados en aspectos relacionados a mercado, preferencias del consumidor, reducción de costos y tiempo para procesar la concha.

La frescura que los BRC desean, está en un rango de menos de 24 horas a un máximo de 48 horas, aunque hay algunos que dan hasta 72 horas. Los BRC consideran que la frescura les permite conservar la concha por más tiempo y reducir el número de docenas que se pierden por el envejecimiento y descomposición de la concha. Además de tener mejor sabor y un olor más agradable que facilita la venta.

Recibir una concha limpia permite que los BRC ahorren tiempo en la preparación de la concha. Otros consideran que la concha se mantiene sana y puede tardar más tiempo en descomponerse. Así mismo, quienes han mencionado que tener la concha limpia mejora la apariencia, son aquellos que mantienen las conchas a la vista de los consumidores.

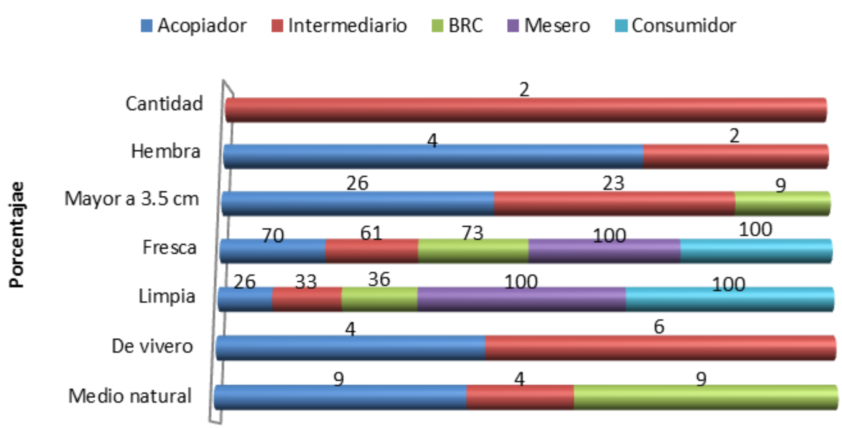
El tamaño que los BRC buscan en una concha está entre los 3.5 cm y los 5cm. En algunos bares y restaurantes se maneja un tamaño mínimo de 3cm no incluyendo la concha (exoesqueleto), es decir, una concha abierta. El 43% que tienen como requisito el tamaño, lo establecen para respetar la talla mínima autorizada por el MARENA y evitar los decomisos del producto. Las otras dos razones para solicitar este requisito, fueron: primero la preferencia del cliente por una concha de más de 3 cm y segundo porque que se pueden poner menos conchas en el platillo, aumentando así el margen de ganancia sobre la concha.

[12] ***Antes de 1996 esta competencia era del Instituto de la Pesca, debido a que el MARENA aún no había sido creado.***

La razón para pedir una concha abierta es reducir el tiempo en la preparación del producto. Prefieren conchas del medio natural (no vivero) por tener sabor más fuerte y sobrevivir más tiempo fuera de su medio. Entre las dos especies, prefieren la concha de *A. tuberculosa*, por su mayor tamaño. En el caso del olor no se dio una explicación, pero se asume que es para evitar que el consumidor final piense que la concha es vieja o en descomposición.

Basados en estos requisitos los BRC consideran que una concha es buena cuando tienen un tamaño mayor a los 4 cm, presentan un color entre rojo y rosado, tienen menos de 48 horas de haber sido extraída y es de la especie A. *tuberculosa*. A esto solo se le puede agregar que no tenga mal olor. De modo que la mayoría de los requisitos se han definido por la comercialización y no por regulaciones formales.

En la Figura No. 17 se observan los requisitos que el comprador solicita a los recolectores, los cuales se transmiten desde los BRC a través de los diferentes eslabones hasta los recolectores con ligeras variantes en cuanto al orden de prioridad por tipo de actor.



Fuente: Elaboración propia

Figura No. 17. *Requisitos solicitados al conchero por tipo de comprador*

El requisito de las cantidades está fuera de las características que debe cumplir la concha. Pero si el intermediario adquiere compromisos de entregar cantidades establecidas en los acuerdos informales que tiene con sus compradores fijos, tiene que cumplir. A pesar de esto, se observa que solo el 2% exige que le entreguen una cantidad fija, cuando no es todo lo que extraen, lo que indica que el restante 98% de los intermediarios no tiene compromiso sobre las cantidades a entregar.

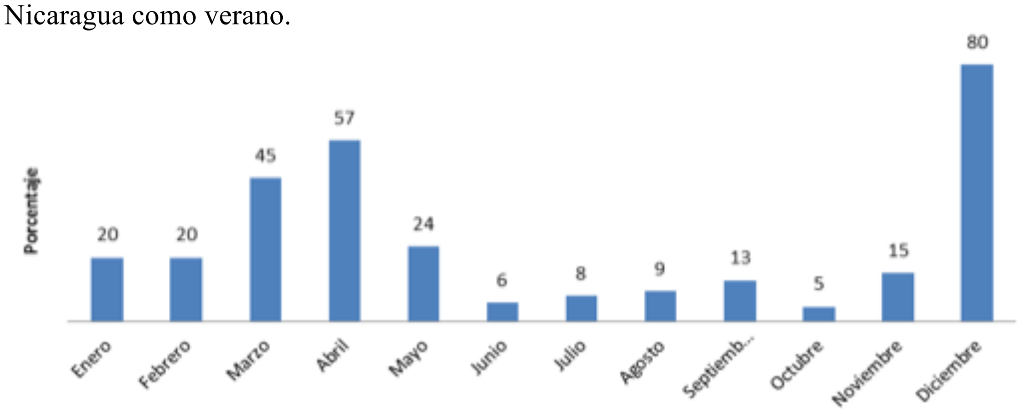
El tipo de especie, en este caso *A. tuberculosa*, solo es demandada por un 4%de los acopiadores encuestados y el 2% de los intermediarios. Desde la perspectiva del conchero, esta especie es preferida porque tiene mayor tamaño, por lo cual es también mejor pagado, tiene mejor gusto, resiste más tiempo viva una vez extraída y es el único tipo de concha que MARENA permite comercializar. Algunos recolectores han llegado a creer que la concha similis tiene veda indefinida.

El tamaño de la concha como se ve, sigue teniendo poca importancia para los eslabones de procesamiento, debido a que la regulación sobre concha, que ha establecido el MARENA, tiene una acción directa sobre la extracción y traslado de la concha, actividad que es realizada por el acopiador e intermediario, no sobre la venta al consumo final una vez procesada. Como se verá más adelante en la parte de acuerdos, los BRC tienen solucionada está parte al solicitar que la concha les sea entregada en sus locales o en la casa del dueño. Lo más importantes para el consumidor final, así como para el mesero que vende tanto a bares como consumidores, son recibir la concha limpia, sin lodo y fresca.

6.1. SITUACIÓN DE LA DEMANDA Y LA OFERTA

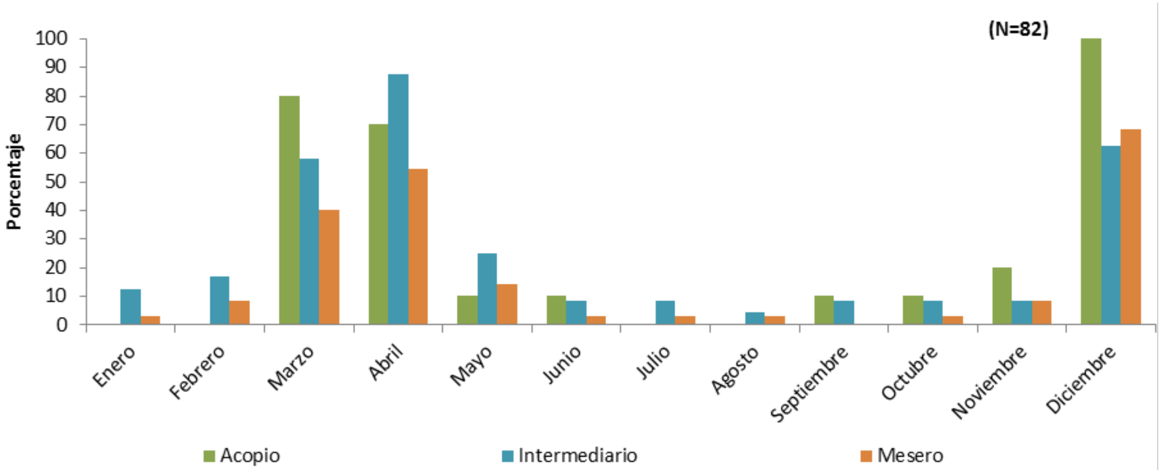
Entender la situación real de la oferta y la demanda de la concha, requiere primero aclarar que en este caso la oferta será igual a las cantidades extraídas por los concheros. Por tanto, la oferta puede ser mayor a las cantidades que los concheros venden.

Las Figura No. 18, muestran que las ventas de los BRC tienen dos picos, uno en marzo-abril influenciado por la Semana Santa y otro en diciembre por las fiestas de navidad y fin de año que coincide con los meses de mayor venta de los diferentes niveles de intermediación (Figura No.19). En términos generales se observa que las mayores ventas se dan entre noviembre a mayo, es decir en periodo seco, conocido en Nicaragua como verano.



Fuente: Elaboración propia

Figura No. 18. *Meses de mayor venta de productos de concha negra en BRC*

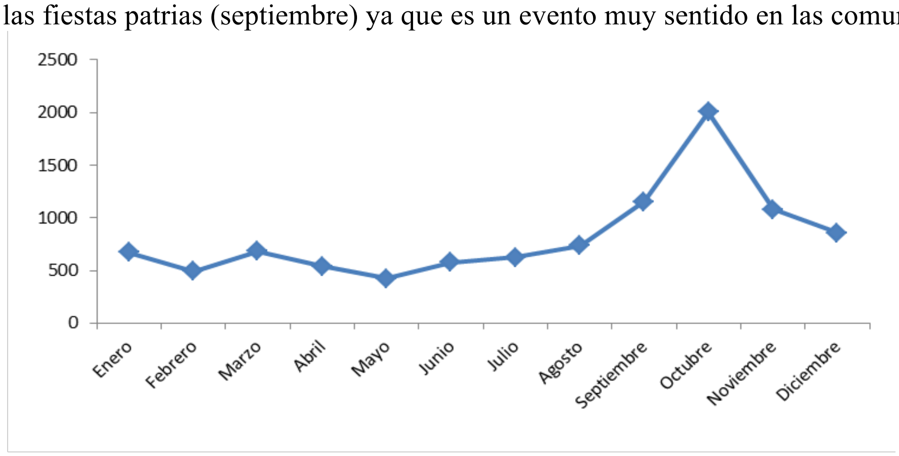


Fuente: Elaboración propia

Figura No. 19. *Meses de mayor venta por acopios, intermediarios y meseros*

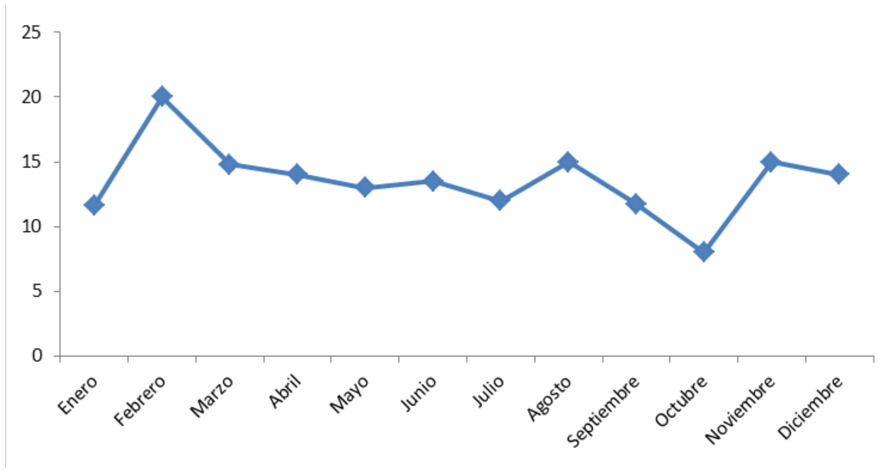
Sin embargo, al observar la Figura No.20, los meses de mayor demanda no se corresponden con los meses de mayor oferta, que van de junio a octubre; es decir durante el invierno (época de lluvia). Marzo es el único mes donde se observa un comportamiento similar entre oferta y demanda de concha negra. Este comportamiento contrario entre la oferta y la demanda resulta interesante, debido a que en los meses de mayor oferta (extracción) son también los meses donde se presenta mayor migración temporal en busca de trabajo como jornaleros de concheros (Figura No.10). Una posible explicación a esto, es que la extracción se utiliza para autoconsumo, debido a la caída del precio y la demanda, la ingesta de conchas remplaza el consumo que se pierde vía falta de ingreso. (Figura No. 21).

Cuando se le ha preguntado al conchero cuales son las mayores motivos para hacer y dejar de hacer la extracción de conchas indican dos aspectos relevantes 1) La escasez de pesca de escama, ya que la concha es una actividad alternativa a la pesca y 2) La mayor demanda de dinero en efectivo entre ellas mencionan las fiestas patrias (septiembre) ya que es un evento muy sentido en las comunidades.



Fuente: Elaboración propia

Figura No. 20. *Meses de mayor extracción de conchas negras (docenas promedio)*



Fuente: Elaboración propia

Figura No. 21. *Precio promedio en los meses de precios altos de la concha (no se entiende)*

6.2. REGULACIÓN FORMAL SOBRE LA CONCHA

La regulación por veda de concha negra y la declaración de dos reservas naturales en áreas de manglares en Chinandega, ha reforzado la posición de poder de los intermediarios frente a los concheros. En cambio desde los procesadores hacia los acopiadores e intermediarios, ha institucionalizado los requisitos informales, como el tamaño y la frescura de la concha. La veda ha pasado de solo ser una regulación de talla –tamaño mínimo para la extracción- a la prohibición de la extracción y traslado de la concha desde las comunidades donde se conchea a los mercados o BRC, por un período de 90 días.

Por otro lado, el aprovechamiento de la concha tanto en reservas naturales como fuera de ellas, requiere de permisos[13]. En el caso de las reservas naturales se requiere del establecimiento de viveros, acompañados de un plan de manejo ambiental revisado y aprobado por el MARENA (MARENA, 1999; MARENA 2008). Fuera de ellas solo se requiere del permiso para trasladar las conchas dentro del territorio nacional (MARENA, 2008). Ver tabla 6

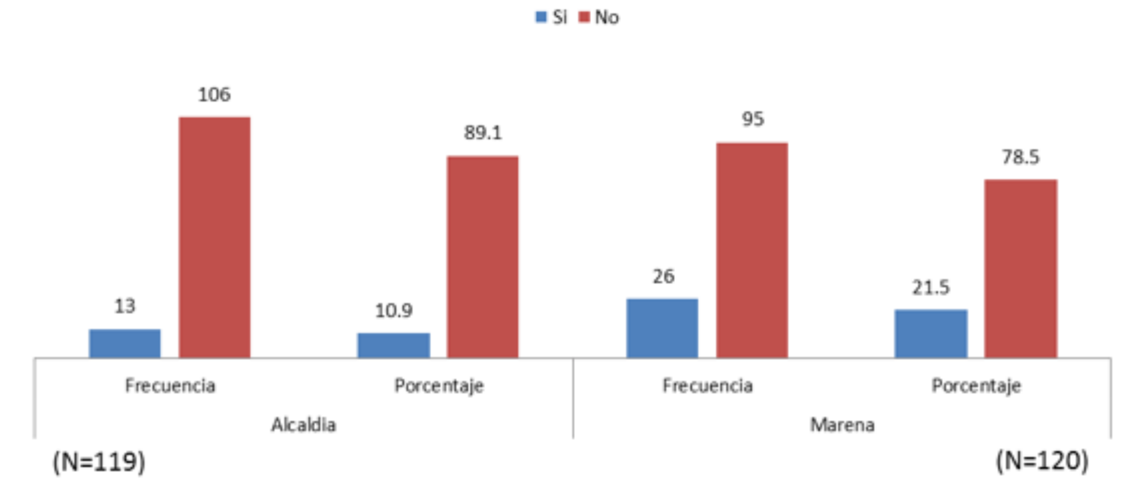
[13] *En el caso de El Realejo este permiso se solicita en la Alcaldía. Pero según la Ley 217, Ley de General del Ambiente y el artículo 2 de la Ley 40, Ley de Municipios, esta responsabilidad podría recaer sobre el MARENA, sin las Alcaldías no tienen las competencias para brindarlo.*

Tabla 6: *Regulación formal sobre la concha*

Regulación	Ley, Decreto o Resolución	Aprobada en	Propósito	Afectados
Veda y talla de la concha Similis y tuberculosa	Acuerdo Ministerial N°69	1985	Veda sobre la concha inferior a los 5 cm, con el fin de garantizar que la concha alcance su madurez y se reproduzca	Conchero, acopiador e intermediario
	Actualización al artículo 13 de la resolución ministerial 007-999	2004	Veda parcial de la concha Similis y Tuberculosa comprendida entre 21 de abril y el 15 de julio de cada año	Conchero, acopiador e intermediario
	Resolución ministerial 028-2008	2008	Establecer criterios técnicos, requisitos y procedimientos para regular la extracción, cultivo y aprovechamiento sostenible de la concha negra	Conchero, acopiador e intermediario
	Resolución ministerial 01.02.2012	2012	Veda parcial de la concha Similis y Tuberculosa comprendida entre 21 de abril y el 15 de julio de cada año	Conchero, acopiador e intermediario
Establecimiento de áreas protegidas y procedimientos para el aprovechamiento de los recursos naturales	Ley General del Ambiente	1996	Establecer normas para la conservación, protección, mejoramiento y restauración del medio ambiente y los recursos naturales	Conchero, acopio e intermediario
	Reformas e incorporaciones a la Ley 40, Ley de Municipios	1997	Dotar a los municipios de las competencias en todas las materias del desarrollo socio-económico y la conservación de los recursos naturales y medio ambiente	Intermediario, conchero
	Reglamento de Áreas Protegidas de Nicaragua	1999	Establecer los procedimientos para el establecimiento de áreas protegidas en sus diferentes formas y la solicitud de administración y explotación de recursos naturales dentro a las áreas protegidas	Conchero
	Resolución Ministerial 04-2003	2003	Establecer 22,061 ha como reserva natural en el Estero de Padre Ramos	Conchero
	Resolución Ministerial 062-2006	2006	Establecer 12,420 ha como reserva natural en el Volcán Cosigüina	Conchero

Fuente: Elaboración propia a partir leyes consultadas

Sin embargo, en la Figura No.22 se observa que 13 de 119 concheros tienen permiso de la Alcaldía y 26 de 120 poseen del MARENA. Dejando dos opciones a los concheros que no tienen permisos: a) vender a una persona que tenga permiso y recibir un menor precio a cambio de un ingreso seguro o, b) llevar la concha por sí mismo y exponerse a un decomiso y multa.



Fuente: Elaboración propia

Figura No. 22. *Concheros con permiso y concheros sin permiso*

Entre las razones por las cuales los concheros no tienen permisos están:

- Desconocimiento de la regulación existente en materia de permisos:
    - "*no sabía que lo necesitábamos*" o, "*son solo para acopiadores, intermediarios y cooperativas*"
- *"No lo dan por ser área protegida"*
- "*no hay presencia de la Alcaldía o MARENA en la comunidad*" (debe entenderse en dos sentidos, por no haber presencia no lo necesita o por no haber presencia no lo ha solicitado)
- La alcaldía no extiende el permiso
- No lo ha renovado
- *"Con el permiso no se puede conchar durante la veda"*
- *"no tiene tiempo ni dinero"*

La regulación del MARENA no afecta directamente a los BRC, debido a que el control se realiza en las comunidades, afectando únicamente a los extractores y los acopiadores que trasladan la concha, lo que es definitivamente más eficiente desde el punto de vista de reducción de costos y efectividad. La posibilidad de visitar cada bar, restaurante o coctelerías en busca de concha que cumpla con la regulación sobre talla y veda no resultaría rentable.

6.3. COORDINACIÓN EN LA CADENA

La coordinación en la cadena de la concha está a cargo de los actores en el eslabón de intermediación, específicamente de los intermediarios, quienes han establecido acuerdos tanto con los BRC como con los acopiadores y concheros. Los primeros acuerdos funcionan para garantizar un mercado y los segundos consolidan los requisitos definidos por los BRC y la regulación.

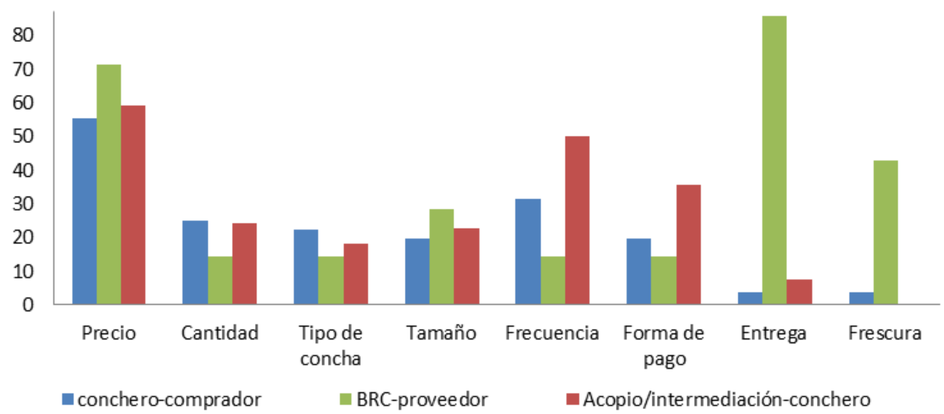
Los meseros en los mercados no necesitan permiso para vender la concha, pero si se les ha informado de la veda, los meses en que no se puede vender y los tamaños mínimos de comercialización. En caso de incumplimiento se les decomisa, aunque, las visitas de control del MARENA no son frecuentes.

En la comercialización de la concha hay dos tipos de meseros:

1. Los que compran directamente al conchero en la comunidad. Han establecido acuerdos bajo los cuales el conchero debe entregar las conchas en la casa del mesero en la misma comunidad o en una comunidad cercana. De manera que ellos (los meseros) corren con las posibles consecuencias de un decomiso por parte del MARENA, Policía o Ejército durante el traslado de la concha desde las comunidades a los mercados.
2. Los que compran de un acopiador, intermediario o conchero en los mercados. No han establecido acuerdos porque la supervisión de la talla y veda en los mercados por parte del MARENA no es frecuente, de manera que no están tan expuestos a las pérdidas por decomiso como los primeros.

Los meseros son quienes trabajan dentro de una estructura más de mercado, donde pueden comprar a cualquier persona que venda concha y comercializar de la misma manera, sin garantizar algún tipo de requisito. El 65 % de los concheros, 85% de los actores en el nivel de intermediación y el 75 % de los BRC que tienen acuerdos establecidos lo han hecho de forma verbal. Los mecanismos de control son inexistentes y las sanciones o castigos para quienes incumplen los acuerdos no son claros.

Los acuerdos, como se aprecia en la Figura No. 23, retoman los requisitos que demandan los diferentes compradores a los concheros y agregan aspectos relacionados con el aseguramiento del flujo comercial. Para su análisis, se agrupo según la interacción que existe entre los actores en: concheros-compradores, acopiadores-concheros y BRC- proveedor. Dando como resultado los siguientes acuerdos:



Fuente: Elaboración propia

Figura No. 23. *Tipos de acuerdos*

<u>**Conchero-Comprador**</u>

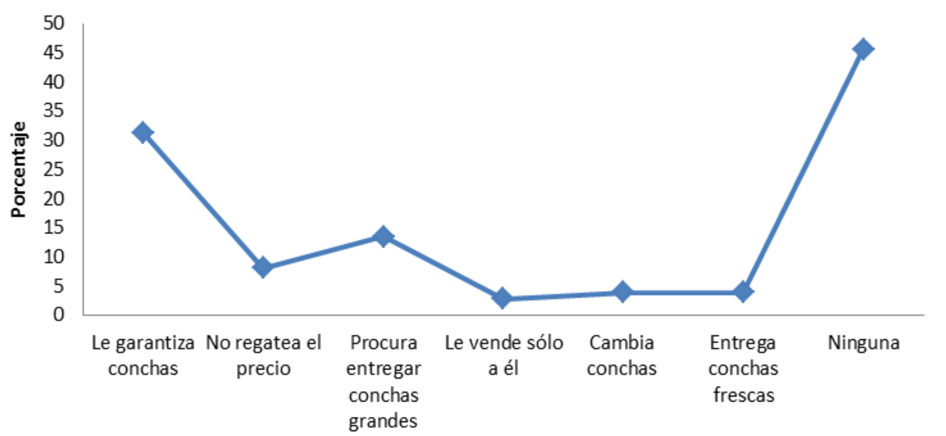
Se ha acordado mantener un precio estable durante todo el año, excepto durante la semana santa cuando se paga un poco más por docena. Los precios acordados al conchero se encuentran en un rango de 8 a 12 córdobas por docena, pero si únicamente se entrega concha *A. similis*, el precio fijado es de 3 a 4 córdobas. Una flexibilidad establecida por el acopiador e intermediario consiste en que si el tamaño de la concha *A. tuberculosa* es pequeña al igual que *A. similis*, se paga el precio de ésta, lo cual constituye un castigo al incumplimiento en el tamaño acordado.

El comprador solicita al conchero que se mantenga la misma cantidad y los concheros que venden directamente a BRC lo hacen una o más veces por semana, pero no a diario. A diferencia de quienes vende a los acopiadores, estos reciben diariamente el producto. La cantidad de conchas recibidas, en ambos casos, puede ser total o parcial.

La especie *A. tuberculosa* se mantiene como preferente; cumpliendo los siguientes requisitos:

- Tamaño entre 4 a 5 cm.
- Entrega inmediatamente después de la extracción o en las siguientes 48 horas.
- Cerrada y en muy pocos casos limpia.
- Pago de inmediato en efectivo a la hora de entrega del producto, sin embargo, hay intermediarios que tienen establecidos pagos en efectivo cada 2 ó 4 días o, pagar con productos para el hogar.

Los acuerdos que más se cumplen son la cantidad y el tamaño solicitado (ver Figura No. 24). El 40% procura cumplir con las cantidades y frecuencia. El 15% busca cumplir con el tamaño de la concha y un 5% esta dispuestos a cambiar las conchas que se quiebran. Sin embargo, el 50% de los concheros no realiza ninguna actividad para cumplir los acuerdos.



Fuente: Elaboración propia

Figura No. 24. *Acciones implementadas por los concheros para garantizar el acuerdo con el comprador*

En caso de incumplimiento de los acuerdos (ver Figura No.23), el conchero reconoce que se le castiga reduciendo el precio de la docena de concha o simplemente no le compran, pero en ningún caso los castigos involucran a más del 25% de los compradores; lo que establece que el 75% de los compradores no castigan o sancionan los incumplimientos, desde la perspectiva del comprador de conchas, el porcentaje de compradores que no castiga o sanciona los incumplimientos disminuye al 63%.

<u>Acopio e intermediación-Conchero</u>

En el eslabón de intermediación, las acciones para garantizar el cumplimiento del acuerdo están: comprarle siempre al conchero, mantener el precio acordado, los meseros son los que más cumplen con este aspecto. Un 22% de los acopiadores y un 3% de los intermediarios reporto dar préstamos a los concheros como una medida para mantener los acuerdos. El22% de los acopiadores, el 36% de los intermediarios y el 3.7% de los meseros no realizan ninguna actividad para garantizar el cumplimiento de acuerdo.

En promedio, el 80%de acopiadores o intermediario no tiene flexibilidad en su forma de castigo hacia el conchero que no cumple los acuerdos. Un 4% exige que le cambien las conchas en caso que estén dañadas. Un 4% compra en concesión, de modo que paga hasta que vende las conchas y un 18% decide no comprar como una forma de castigo.

BRC-Proveedor

Los BRC tienen como principales requisito en sus acuerdos la entrega de la concha en el negocio, la frescura y mantener un precio estable, entre ellos:

- El 85% de los BRC quiere que la concha sea entregada en la el negocio
- El 71% ha fijado un precio estable durante el año excepto en la Semana Santa y en diciembre, donde el precio se puede modificar de acuerdo a la demanda
- El 43% quiere una concha fresca, de preferencia de no más de 24 horas después de la extracción
- Quieren un flujo constante de la concha, en algunos casos prefieren llamar al proveedor para indicar la cantidad y día de entrega
- Que el tamaño sea mayor de 4 cm, para cumplir con la regulación del MARENA.
- Que la concha este limpia y cerrada
- Algunos BRC piden sólo la carne de la concha junto al líquido que genera al ser abierta
- En pocos casos se tiene el acuerdo de recibir la concha en concesión
- La acción que más realizan para mantener el acuerdo es comprarle siempre (72%)

Al igual que en los casos anteriores, un 63% de los BRC no tienen flexibilidad en su forma de castigar las faltas de sus proveedores, el 33% no le compra o le compra más a otro proveedor, en el caso que tenga más de uno y 2% le reduce el precio por docena, le regresa las conchas o habla con los proveedores para solicitarle que no vuelva a faltar al acuerdo, de lo contrario buscarían otro proveedor.

CONCLUSIONES

Los canales de comercialización de la concha negra están monopolizados por los intermediarios que cuentan con auto y permiso del MARENA o Alcaldía. Los concheros tienen serias dificultades: para llevar el producto a los mercados por la distancia, por falta de asociaciones y cooperación entre concheros, inexistentes condiciones para conservar la concha higiénicamente por más de 48 horas y el poco conocimiento sobre la regulación del MARENA para el aprovechamiento de la concha.

La veda establecida por MARENA afecta a los concheros, debido a que coincide durante los meses donde la demanda de éste producto es alta y las cantidades extraídas son bajas; afecta a los intermediarios y acopiadores, ya que si no cumple la demanda de los BRC, estos cambian de proveedor aumentando así el poder monopólico de aquellos intermediarios que no cumplan con la veda. La regulación del MARENA podría estar reforzando la asimetría en el poder de negociación entre los concheros y los intermediarios, ya que únicamente está dirigida a los extractores, y son estos los que tienen que asumir el costo de la regulación y los castigos por la no entrega en tiempo y forma.

La concha es un producto periférico, complementario en una oferta alimenticia de mariscos. Para incrementar su dinámicas, de manera que se cubran los costos de inversión, se deben ampliar y/o diversificar alternativas de colocación, o estimular un proceso de diferenciación de los productos en que se incluye. En promedio un negocio BRC y mesero tarda de tres días a una semana para mover entre 20 a 40 docenas de conchas es ahí donde surge la necesidad de diversificar el mercado.

Para los concheros, las extracciones es una actividad complementaria que realizan en periodos de baja en la pesca y/o en las fechas de poca demanda laboral. La producción de la concha a través de viveros es una actividad potencial, para la generación de empleo y desarrollo económico para las zonas rurales por eso se debe fomentar esta actividad.

La concentración del mercado en pocos intermediarios es la manera más eficiente de reducir los costos de transacción *–transporte y legalización.* Sin embargo, esto a la vez, le confiere un poder de mercado con los cuales definen precios y castigos severos al no comprar las conchas que no cumplen con sus requisitos. Una intervención en facilitar la tramitología de los permisos a los extractores es una alternativa importante de acción.

La cadena de valor de la concha negra, es corta y de bajo valor agregado. Se caracteriza por poco o nulo proceso y cuatro eslabones bien definidos (extracción, intermediación y procesamiento-comercialización). El cultivo de conchas (vivero) han tenido serias limitantes dada la inversión de fuerza laboral y un precio controlado por los intermediarios.

El crecimiento de la actividad demanda una agregación de valor a través de procesos de diferenciación del producto final que se oferta directamente al consumidor, y el incremento de los volúmenes que fluyen actualmente, es decir, pasar de un producto periférico, a uno con presentación propio de consumo en todo el año.

RECOMENDACIONES

Los resultados dejan ver la necesidad de realizar estudios para determinar las posibilidades de aprovechar el potencial del consumo de la concha en la región centroamericana, sobre todo en los países de El Salvador y Guatemala. Para ello es necesario avanzar en el conocimiento de la tramitología básica de los permisos, el CIDEA podría jugar un rol importante en la capacitación y acompañamiento de las iniciativas que incluyan procesos de vivero.

Se requieren estudios para determinar realmente en que meses del año la concha entra en etapa reproductiva, ya que los concheros aseguran que la reproducción se da más en agosto y septiembre. Si esto fuera cierto, se debería pensar en mover la veda, lo cual podría beneficiar tanto a la concha, a los concheros y a los consumidores. En estos meses la demanda de concha es baja, lo que disminuye los precios, los concheros realizan otras actividades por lo cual dejan de conchar y además según Sandoval, E. et al (2007), en invierno la concha está más propensa a contaminarse, representando una amenaza a la salud de los consumidores.

El desconocimiento de las enfermedades que pueden ser transmitidas por el consumo de concha y el hecho de que la concha es consumida más por un segmento de ingreso bajo (Lazarich, 2009), lleva a mantener requisitos de baja calidad sobre la concha, lo que no permiten la innovación en cuanto a la preparación de nuevos platillos, sino que se sigue elaborando los ya tradicionales, como son los cocteles y sopas de conchas negras. Un proceso de mejora y monitoreo de los estándares de sanidad debería ser aplicado a lo largo de la cadena de valor.

Los BRC son quienes imponen los requisitos que debe cumplir el producto y los intermediarios transmiten estos requisitos a los niveles primarios. Lo cual, representa una oportunidad para mejorar la higiene del producto a través de la cadena, ya que a través de ellos se puede llevar una campaña de educación y un proceso de control sanitario, de manera que ellos sean el canal trasmisión de estas normas.

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TOPIC AREA:
VALUE CHAIN ANALYSIS
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VALUE CHAIN ANALYSIS OF CARP POLYCULTURE SYSTEMS IN SOUTHERN NEPAL

Marketing, Economic Risk Assessment & Trade/Activity/09MER11UM

FINAL INVESTIGATION REPORT

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ABSTRACT

The objectives of this study were to develop a Value Chain Map of carp polyculture in the Chitwan District of Nepal, and to identify areas for improvement and further research of the aquaculture sector in Nepal. This study primarily covered the Chitwan District. Interviews were performed in July 2012 with 3 hatchery and nursery owners, 31 fish farmers, and 10 market sellers, including the majority of sellers at local markets. Small-Scale Farmers (n = 22) were those who produced 100 kg or less of fish per year and did not sell any fish to markets, while Commercial Farmers (n = 9) produced greater than 100 kg fish per year and sold fish to markets. Among Small-Scale Farmers, 55% of all fish produced was consumed by the farmer's family, while 45% was sold to neighboring households. Among Commercial Farmers, 46% of fish produced was sold to local markets, 32% kept for home consumption, and 22% sold to neighboring households. Local Market Sellers prepared and sold the fish in the market, purchased it directly from the farmer, and transported it by way of bicycle or motorbike. In this study, Small-Scale Farmers were found to be largely content with the production of fish for home consumption. However, 20 of the 22 farmers also wanted to increase the size of their existing pond or build additional ponds in order to produce more fish to sell. All nine commercial farmers interviewed also desired to increase production and ship fish to distant markets, such as those in Kathmandu. There is high demand for fish in Kathmandu, and a preference for fresher, Nepali-raised fish. Among the Private Hatchery, Private Nursery, and Government Hatchery personnel interviewed in this study, only the latter reported to have a successful, self-sustaining business. In order to maintain a Chitwan-run, prosperous aquaculture sector, improvements must be made through training of private hatchery owners by Government Hatchery personnel. Currently, the Government Hatchery aims to help local fish farmers by raising and selling fingerlings at a price lower than that of the private hatcheries, which creates incentive for farmers not to purchase fingerlings from private sellers. Additionally, the Government Hatchery was reported to raise over 1000 kg of full-grown fish every year, which it also sold to consumers at a lower price than fish sold at local markets, again out-competing local fish farmers.

INTRODUCTION

Although aquaculture has been practiced in Asia for thousands of years (FAO, 2012), it is fairly new in Nepal. It was not until the 1940s that the country began raising fish, and an additional 40 years passed before any significant progress was made in the field (FAO, 2012). Considering Nepal's late start in aquaculture practices, it is no surprise that the country has yet to contribute substantially to the huge volume of Asian aquaculture production (Asia produced 92.5% of the world's total aquaculture in 2008) or benefit largely from the economic improvements aquaculture has created (FAO, 2010). Recently, however, Nepal has shown marked increase in aquaculture production (Figure 1). Carp polyculture has been developed as the most popular system in the country, and research has been made into cage fish culture, rice-fish culture, and the production of cold-water cultures of species, such as snow trout and rainbow trout at higher altitudes (FAO, 2012). Additionally, aquaculture in Nepal has been shown to benefit rural communities by providing an important supply of protein and additional income generation, and by empowering women who care for fish ponds (Bhujel et al., 2008).

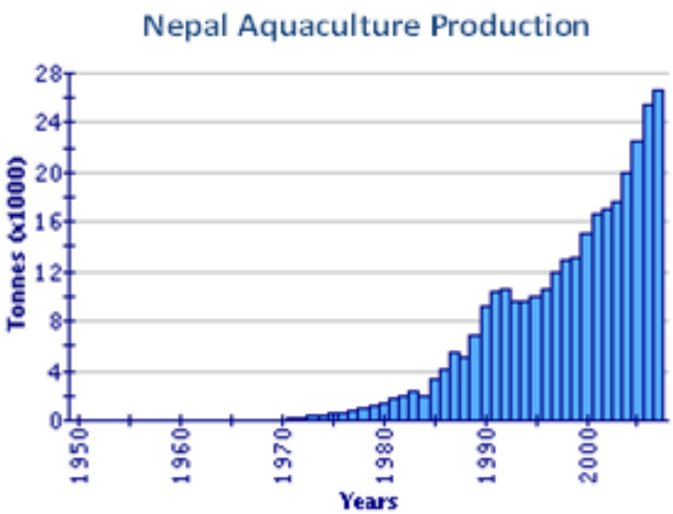

***Figure 1**. Reported aquaculture production in Nepal since 1950. Figure copied from FAO.org.*

Because aquaculture in Nepal has recently expanded, little is known about the activities responsible for bringing cultured fish from creation in the hatchery to ultimate disposal by the consumer. In order to determine the manner in which the Nepali carp polyculture industry has developed, and to gain insight into specific ways it can be improved, an assessment must be carried out. This can be done through a value chain analysis, which will investigate the relationships between the stages of production, processing, and distribution in the system, in turn providing valuable information regarding areas for improvement within the market flow of the product. This study will focus on carp polyculture systems in the Chitwan District, which is a small area that acts as a representative of Nepal carp polyculture systems throughout the country.

OBJECTIVES

1. Develop a Value Chain Map of carp polyculture in the Chitwan District of Nepal.

2. Identify areas for improvement and further research of the Nepal aquaculture sector by analyzing the results of interviews on the carp polyculture value chain conducted in the Chitwan District of Nepal.

MATERIALS AND METHODS

Study Area –

This study primarily covered the Chitwan District in the southern Terai region of Nepal. Chitwan is made up of a number of villages (called Village Development Committees or VDCs) that rely on agriculture for their primary source of income. Many villagers in Chitwan also practice aquaculture. The locations of Kathar, Khairahani, and Phaphaini contain the highest concentrations of aquaculture ponds in the region, and were therefore the focus of this study.

In cases where the product was traced outside of Chitwan, interviews were conducted beyond the District's borders. This included the locations of the Kalimati and Paknajol Markets in Kathmandu.

Data Collection –

Interviews were carried out with hatchery and nursery owners, fish farmers, and market sellers for approximately three weeks in July 2012. In order to determine the stages of the value chain, interviews were first initiated with fish farmers. Information was obtained from this group regarding the movement of hatchlings and adult fish, and additional interviews were then conducted with hatchling managers and fish sellers. The total number of fish ponds in the villages of Kathar, Khairahani, and Phaphaini were unknown. We decided that interviews of ten farmers from each location would serve as a valid representation of each respective locality. Regarding fish sellers, a majority of those present at each Chitwan market (Parsa, Thadi, and Narayanghar) were successfully interviewed. This included three of four sellers in Parsa, two of three sellers in Thadi, and two of three sellers in Narayanghar. In Kathmandu, the majority of sellers approached would not consent to an interview. In this area, all of those who agreed to conversation were included. This was a total of three individuals (two from the Kalimati Market and one from Paknajol). Table 1 summarizes the total number of respondents from each location in the study.

Table 1. Number of respondents

Location	Kathar	Khairani	Phaphaini
Fish Farmers	10	10	10

Location	Parsa	Thadi	Narayanghar	KTM Kalimati	KTM Paknajol
Fish Sellers	3	2	2	2	1

Location	Kathar	Bhandara
Hatchery	1	1
Nursery	1	0

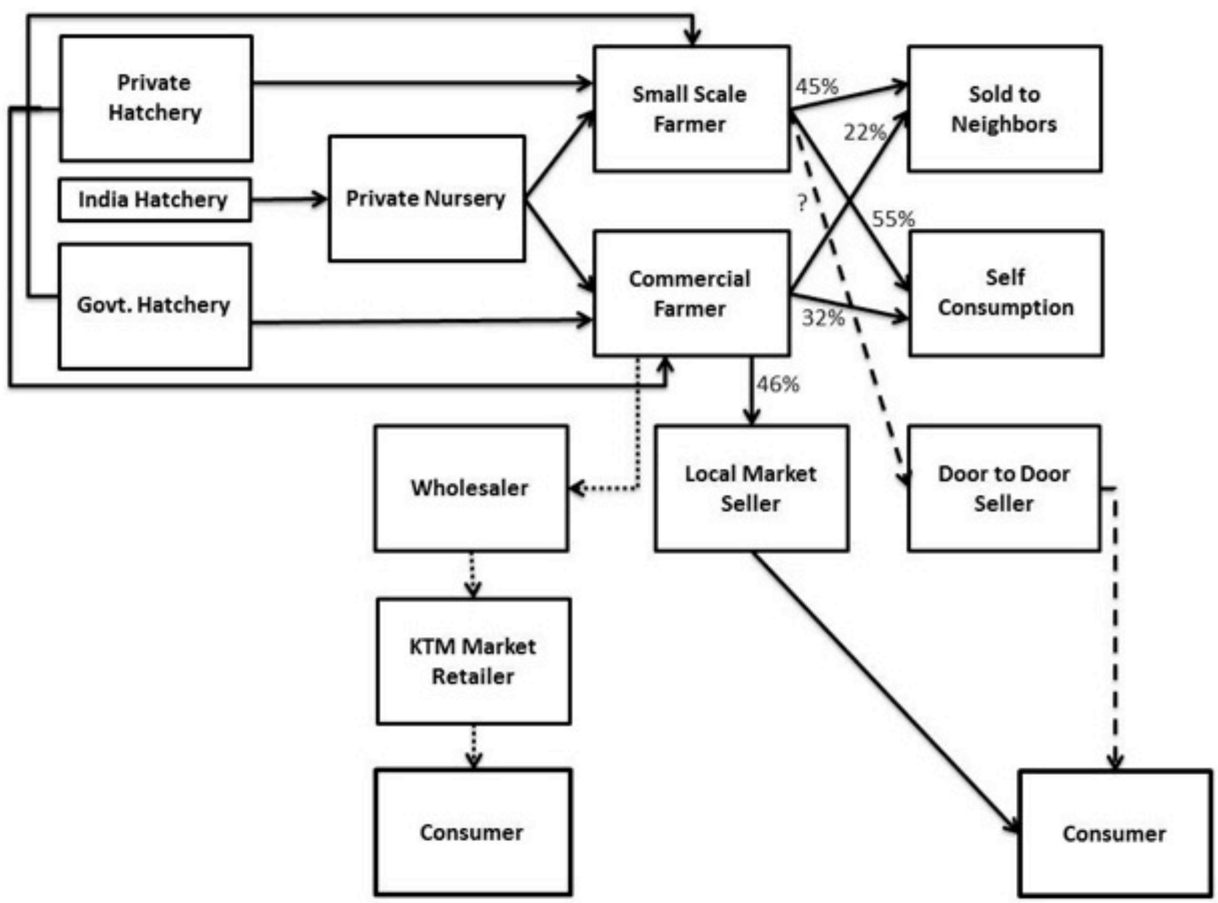

Figure 2. *Value Chain Map of carp polyculture systems in Chitwan, Nepal.* Dashed lines represent activities known to occur for which data was not obtained. Dotted lines represent market flow still under development

__**Data Analysis –**__ Data from each respondent was collected through personal interviews that asked questions regarding such topics as the expenses, profits, and challenges in each respective business. For Value Chain Mapping, hatchlings were considered the major input to the system, and their movement was traced among different actors in the chain. Small-Scale Farmers (n = 22) were considered all those who produced 100 kg or less of fish per year and did not sell any fish to markets. Commercial Farmers (n = 9) were considered all those who produced greater than 100 kg fish per year and sold fish to markets. Percentages of marketable fish moved (consumed, sold, etc.) by Small-Scale and Commercial Farmers were determined by averaging the responses given by each farmer regarding the flow of products. Percentages of the movement of hatchlings from the Private Hatchery, Government Hatchery, and Private Nursery could not be determined because hatchery and nursery owners did not keep data regarding the size of farm to which hatchlings were sold. Hatcheries were distinguished from nurseries because the latter did not possess their own broodstock.

RESULTS AND DISCUSSION

Figure 2 summarized the Value Chain derived from our interviews. All fish farmers interviewed in Chitwan were found to obtain fingerlings from a privately owned hatchery, the government-run hatchery in Bhandhara, or a private nursery within the District. The nursery owners obtained hatchlings from Calcutta, India, which they believed produced higher quality fish than local hatcheries. The nursery raised hatchlings until they became fingerlings, at which point they were sold. Each hatchery had its own broodstock. The government hatchery was operated as a branch of the national government, the Nepal Agricultural Research Council (NARC), which serves to "conduct agricultural research in the country to uplift the economic level of the people." (NARC, 2013).

Fish farmers were found to buy fingerlings from different hatcheries for different reasons. In Kathar, for example, all ten farmers interviewed reported to have purchased fingerlings from the Government Hatchery because it sold fish for the lowest price. In Khairahani and Phaphaini, however, all of the farmers reported to have purchased fingerlings from the private hatchery or nursery because quality of fish was higher at these locations.

Among Small-Scale Farmers, it was found that 55% of all fish produced was consumed by the farmer and the farmer's family, while the remaining 45% of fish produced was sold to neighboring households. Among Commercial Farmers, 46% of all fish produced was sold to local markets, 32% was kept for home consumption, and 22% was sold to neighboring households. In the case of the Local Market Seller, the same individual who prepared and sold the fish in the market bought it directly from the farmer and transported it by way of bicycle or motorbike. Some percentage of fish raised by Small-Scale Farmers was purchased by bicycle sellers, who then rode door-to-door throughout villages making sales (Door-to-Door Seller). These individuals were also known to take purchased fish directly to local markets for sale. Farmers did not have information regarding the location of the ultimate sale of fish purchased by individuals on bicycles, but unanimously reported that all such transactions resulted in sales at the market. Because it was known that this was not always the case, movement of fish to the Door-to-Door Seller within the Value Chain Map is represented by a dashed line, and the percentage of fish sold in this manner is denoted by a question mark.

Dotted lines in the Map represent a series of transactions that occur in Chitwan aquaculture, but have not yet been quantified. All of the cultured fish sold in Kathmandu was reported to have come from India, where purchase and transportation were said to have been organized by a single individual (the Wholesaler), who then sold to individual retailers of the market. However, several farmers in Chitwan claimed to have been in the process of selling their fish in the Kathmandu (KTM) Market. Similar information was given in relation to the Pokhara fish market, but this site was not visited in this study and was therefore not included in the Map. Because the sale of these fish at Kathmandu is in question, no proportions of sales could be defined for this transaction.

Many aquaculture ponds in the Chitwan District were constructed through international development projects focused on providing fish — an important source of high quality animal protein — to low-income families with limited diets. It is therefore no surprise that the majority of fish farmers in Chitwan raise fish in small ponds and keep most of what they harvest for home consumption. Such small-scale subsistence aquaculture has been viewed as a success in the region, not only because it has succeeded in providing fish to families, but it has also led to empowerment of women and increased income generation (Bhujel et al., 2008). In this study, small-scale farmers were found to be largely content with the production of fish for home consumption. However, 20 of the 22 farmers also stated that they wanted to either increase the size of their existing pond or build additional ponds in order to produce more fish for the purpose of selling. An analysis of the demand of neighbors without fish ponds (45% of cultured fish from small-scale farmers were sold to neighbors) was not quantified in this study, so it is uncertain if an increase in production of fish by these farmers could be sold to neighbors. Regarding the possibility that increased production from this group could be sold at local markets, all sellers at local markets stated they were meeting consumer demand with the current supply of fish, so it is unlikely that increased production of fish could be sold at this venue, given current market trends. In order to determine if increased production from small-scale farmers could be sold for profit, further research must be conducted on market demand.

Of the Private Hatchery, Private Nursery, and Government Hatchery representatives interviewed in this study, only the latter reported to have a successful, self-sustaining business. The Private Hatchery had to stop production for a year because of problems maintaining broodstock and managing finances, and the Private Nursery was reliant on Indian broodstock and hatchlings. In order to maintain a Chitwan-run, prosperous aquaculture sector, improvements must be made in private hatcheries. This can be done through training of private hatchery owners by the Government Hatchery, which is meant to aid local people. Currently, the Government Hatchery aims to help local fish farmers by raising and selling fingerlings at a price that creates no profit. This selling price is lower than that of the private hatcheries, which creates incentive for fish farmers to purchase fingerlings from the government instead of private sellers. By creating this relationship, the Government Hatchery is actually out-competing private hatcheries. Additionally, the Government Hatchery reported to raise over 1000 kg of full-grown fish every year, which it sells to consumers at a lower price than fish sold at local markets. Similarly, by selling at a lower price, the Hatchery is out-competing local fish farmers. If it is truly the goal of the Government Hatchery to aid the people, it must cease selling fingerlings and full-grown fish at discounted prices and begin to provide training for hatchery owners and farmers in need.

All nine of the commercial farmers interviewed expressed a desire to increase production and ship fish to distant, larger markets such as those in Kathmandu. There is high demand for fish in Kathmandu, and there is a preference for fresher, Nepali-raised fish over fish shipped from India. Because the majority of fish sold in Kathmandu is shipped from India, there exists a market for Nepali-raised fish in this location. The Wholesaler interviewed in Kathmandu reported to sell an average of 1,800 kg of fish every weekday. He expressed his preference for buying fish in Nepal, but stated that Nepal is currently not able to meet his demand. Additionally, he explained that there are few ice plants in Nepal that can easily and cheaply supply his business.

Although fish farmers in Nepal might not currently be able to supply enough fish to meet the demand of 1,800 kg/day, they would still be able to sell a significant amount of fish in Kathmandu if they were able to establish efficient methods of fish transport and develop working relationships with fish retailers in the city. Unfortunately, it will take time to develop this infrastructure. Data collected in this study suggests the greatest opportunity for economic expansion of the aquaculture industry in Nepal is for commercial farmers to sell greater volumes of fish in big-city markets like the Kalimati Market in Kathmandu. This would lead to a decrease in reliance upon Indian-raised fish to feed Nepali consumers, and it would create greater economic benefit in the Nepali aquaculture industry.

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