Ration Reduction, Integrated Multitrophic Aquaculture (Milkfish-Seaweed-Sea Cucumber) and Value-Added Products to Improve Incomes and Reduce the Ecological Footprint of Milkfish Culture in the Philippines

Mitigating Negative Environmental Impacts/Experiment/09MNE02NC

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ABSTRACT

In the Philippines, cage culture of milkfish in marine environments is increasing. The practice uses high stocking densities, with significantly greater inputs of artificial feeds which more often than not, have led to excessive feeding and consequently excessive nutrient loading in receiving waters, exacerbating problems with pollution. These could have contributed to occurrence of periodic fish kills in areas of marine milkfish culture clusters. In marine cage culture, about 80% of variable expenses are attributable to feed costs. Experiments were conducted to compare production characteristics of milkfish fed on alternate days versus those raised on daily feeding in marine cage culture. Fish were fed either daily or every other day using a reduced feed ration at 7.5% of fish biomass at the start of culture down to 3% of fish biomass towards harvest. We showed this ration level was as effective as the industry standard that begins at a rate of 10% average body weight. Morevover, we had previously found that milkfish reared in brackishwater ponds on an alternate day feeding scheme using the reduced ration level produced a 56% cost savings in feed with little impact on total yield relative to fish raised on a daily feeding protocol. In the present study, survival rates (~ 90%) were comparable between the control fish fed daily and groups fed on alternate days in marine cages. Similarly, total harvested biomass of fish in the alternate day and daily feeding groups was similar as was the harvest value, although fish on the alternate day feeding scheme grew slightly less. The amount of feed and the corresponding cost of feeds consumed were significantly lower in stocks that were fed on alternate days compared with those fed daily ($P < 0.05$). Feed conversion ratio (FCR) was lower in the alternate-day fed group (FCR = 2.46) relative to stocks fed daily (FCR = 3.59). Overall, the results demonstrate that feed costs can be reduced by around 32% in stocks fed on alternate days, which yields an estimated 20-25% improvement in production efficiency relative to raising animals on a daily feeding protocol. Hence, a significant costs savings with reduced impact of nutrient loading in the environment is likely to be realized for farmers who adopt an alternate day feeding scheme in raising milkfish in marine cages.

Although aquaculture is an important and increasingly intensive industry in the Philippines the concept of Integrated Multi-Trophic Aquaculture (IMTA) has not been systematically or widely practiced in aquaculture production. Although polyculture or integrated aquaculture has been practiced to some extent, the complementary trophic roles of various aquatic organisms in recycling nutrients and energy during the production cycle to contain the solid and liquid waste that pollute the aquatic environment has not been fully explored or utilized. Extensive aquaculture system where stocking density is low and the cultured species are totally dependent on the natural productivity of the culture environment for growth and sustenance is undoubtedly a sustainable practice but volume of harvest is low. On the other hand, intensive/semi-intensive aquaculture of a single species (monoculture) where stocking density is very high and relies heavily on high feed inputs, like in intensive shrimp culture, is not sustainable because of the release of enormous amounts of nutrient-rich wastes that pollute the coastal environment. Applying IMTA in intensive aquaculture systems will lessen its negative impact to the environment and with proper adjustments in the

stocking density and feed inputs, will make the practice sustainable. The potential is high for the application of IMTA in tropical aquaculture production systems to address two important global targets: increase aquaculture productivity for food security and protection of the aquatic culture environment.

The concept of IMTA was applied and tested in the current work on milkfish. For the trials in brackishwater ponds, six pond compartments with an area of 700 m^2 were stocked with milkfish fingerlings at a stocking density of 0.5 fish/m^2. Three ponds were stocked with sea cucumber at a density of 0.2 individuals/m^2. The seaweed *Gracilaria bailinae* was used as biofilter. Preliminary experiments were conducted and showed that high mortalities occur when sea cucumbers are stocked directly into the pond, with total mortality recorded within 1 week, which likely results from the silty-muddy substrate typical of brackishwater ponds in the Philippines. Culture of sea cucumber in cages set in ponds where milkfish are stocked was tested as an alternative. Survival of sea cucumber was very good (78-86%). The presence of sea cucumber or the sea cucumber cages likewise did not have any effect on the growth of milkfish in both weight and length. Thus, sea cucumber can produced as a value-added product in brackishwater pond production of milkfish. The seaweeds Gracilaria bailinae grown in canals between ponds initially showed good growth but later died off after alternating days of intense heat followed by days of heavy rains which lowered the salinity in the pond below 25 ppt.

For the trial in marine cages, the seaweed *Kappaphycus alvarezii* is used as biofilter. Milkfish fingerlings were randomly stocked in 6 units 5x5x3m cages at a density of 35 fish/m^3. Sea cucumbers were stocked under three of the cages. However, 100% mortality was observed during the 1st sampling (2 weeks). Trials on sulfide tolerance of sea cucumbers show that sea cucumbers cannot withstand the high sulfide environment under cages especially if the site has been used for mariculture operations for extended periods or as sulfide builds up with increasing biomass of stocks and hence increasing intensity of feeding. On the other hand, sea cucumbers seem to thrive in shallower marine pens thus co-culture of milkfish in pens needs to be tested. Although the feasibility of co-culture of milkfish and seaweeds in cages could not be determined in the present study due to outbreak of ice-ice disease resulting in mortalities in the seaweeds, *Kappaphycus alvarezii* grown in cages adjacent to the fish cages generally show good growth with increasing biomass of the cultured stocks and hence increasing intensity of feeding. These observations and information in the literature on the capacity of both *Gracilaria* and *Kappaphycus* to extract excess nutrients from the rearing water suggest that integrated culture of milkfish and seaweeds is feasible.

Information on the benefits of reduced feeding strategies as well as integrated and polyculture culture systems of species that are compatible with milkfish were disseminated through season-long training for community-based livelihood projects through a series of workshops. Skills development workshops were likewise conducted on milkfish processing and value-adding (e.g. deboning, production of flavoured deboned milkfish though smoking and use of various marinades) for women in major milkfish growing areas, as well as processing of seaweeds and preparation of various recipes using seaweeds for women in major seaweeds growing areas, respectively, as potential supplemental livelihood activities. The beneficiaries include 4 fishers' organizations from different coastal villages in Guimaras, fish and seaweeds farmers in Roxas (Capiz), Hamtik and Pandan (Antique) and womenfolk in Tigbauan (Iloilo).

INTRODUCTION

Milkfish (*Chanos chanos*) culture is the largest finfish aquaculture industry in the Philippines with total production of 250,000 metric tons annually (Table 1; DA-BAS 2011). As part of the Philippine government's food security and poverty alleviation programs, expansion of milkfish culture is a high priority (Rosario 2006) both to wean fishers off capture fisheries and to increase income of farmers and fishers alike, whose poverty levels are disproportionately high (Rivera et al. 2006). Milkfish continues to be a top aquaculture commodity of the Philippines primarily because it is easy to culture and can be grown in a wide range of environments. Milkfish thrives in freshwater, brackishwater, marine and even hypersaline habitats. Milkfish production is increasing rapidly with much of the production moving away from traditional culture in brackishwater ponds to fish cages in coastal marine waters, with a 98% increase in marine cage culture seen between 2005 and 2010 (see Table 1;

DA-BAS 2011). Cage culture of milkfish in coastal marine environments is done at higher densities and with significantly greater inputs of artificial feeds. Using this practice, however, has led to wastage of artificial feeds and excessive nutrient loading in receiving waters (Sumagaysay et al. 2004), exacerbating pollution problems and contributing to periodic fish kills in areas of intensive milkfish culture.

Currently, milkfish are fed daily at levels ranging from 10% to 4% of body weight (BW) depending on fish size (Coniza 2009). Based on our recent findings in phase I of the AquaFish CRSP, reducing the initial feeding rates from 10% BW to 7.5% BW produce similar growth rates to those seen in response to feeding at in milkfish grown in flow through seawater tanks (De Jesus-Ayson and Borski 2009; De Jesus-Ayson and Borski 2010). We also found that a > 50% cost savings in feeds is achieved when milkfish grown in brackishwater ponds are fed the reduced feeding rate on alternate days rather than the typical daily feeding protocol. Yield was not compromised with the alternate day feeding strategy. These results suggest that a similar cost savings might be found with milkfish raised in production scale sea cages. Hence, one objective of these studies was to evaluate if reducing feed inputs through alternate day feeding might provide a cost savings to milkfish production in sea cages.

The concept of Integrated Multi-Trophic Aquaculture (IMTA) systems uses various organisms having different feeding niches in a polyculture system. In temperate areas, IMTA is practiced by combining, in appropriate proportions, the cultivation of fed aquaculture species (salmon) with inorganic extractive aquaculture species (brown algae) and organic extractive aquaculture species (mussel). The aim of IMTA is to increase long-term sustainability and profitability per cultivation unit (not per species in isolation as is done in monoculture), as the wastes of one crop (fed species) are converted into fertilizer, food and energy for the other crops (extractive aquatic species), which can in turn be marketed for additional income. In this set up, all components in the culture system have an economic value and play key roles in the recycling processes of the system.

In modern coastal integrated mariculture, shellfish and seaweed are cultured in proximity to net pen fish culture (Troell et al. 1997). The red algae *Kappaphycus alvarezii* (Hayashi et al. 2008) and *Gracilaria heteroclada*, seaweed species widely distributed in the Philippines (Luhan et al. 2006) efficiently take up dissolved inorganic nitrogen in effluents from fish holding facilities. Seaweed production and quality are often enhanced in areas surrounding fish net pens than elsewhere (Troell et al. 1997). *K. alvarezii* is the most economically important seaweed in the Philippines. Monoculture of this seaweed in coastal waters of the country had generated high revenues to the small fishers. The farming of *K. alvarezii* in close proximity to fish cages has not been tried, though polyculture with grouper in cages was found to be economically feasible (Hurtado-Ponce 1992). On the other hand, the sea cucumber (*Holothuria scabra*) is an economically important species that is currently overexploited in the Philippines and worldwide. It feeds on detritus and algae and as such is an excellent species for polyculture with other farmed fauna (Purcell et al. 2006). This project will test the viability and economic feasibility of an integrated culture of milkfish, seaweeds and sea cucumber (e.g. sandfish) that is more environment-friendly and will bring added income to coastal communities.

Milkfish is traditionally traded in chilled or frozen form. However, there is a growing trend towards processing and production of value-added products. Marketing of milkfish outside the Philippines is constrained by the fact that it has numerous bones and spines embedded in its flesh. Women have been deboning milkfish for a long time. As part of a longterm training project, women will be trained on this and additional processing and value-adding techniques (e.g. deboning, smoking, marinating deboned milkfish in various flavors). Capacity building in this area will provide potential supplemental income to women.

OBJECTIVES

The general objective of this work is to reduce feed inputs and promote integrated culture for a more cost effective milkfish farming and reduce its environmental impacts while also providing additional income from seaweed and sea cucumber culture. The specific objectives are the following:

1. To compare alternate day feeding to the standard daily feeding on milkfish production in cages in coastal marine water[1]
2. To establish a more environmentally-friendly milkfish production system in cages or pens using the concept of integrated culture.
3. To evaluate the feasibility of co-culture of milkfish with seaweeds and sea cucumber in brackishwater ponds and in marine cages
4. To disseminate information on feeding rates and demonstrate the economic feasibility of integrated culture systems through season-long training for community-based livelihood projects.
5. To conduct skills development training workshops on milkfish processing and value-adding (e.g. deboning) for women in major milkfish growing areas as a potential supplemental livelihood opportunity.

METHODS, RESULTS AND DISCUSSION

1. Effect of alternate day feeding on marine cage culture of milkfish

For the trial in marine cages, milkfish fingerlings were randomly stocked in 6 units 5x5x3m cages at a density of 35 fish/m^3. Milkfish stocks in 3 of the cages were fed daily using SEAFDEC formulated feeds following the recommended daily feeding rate (see Table 2), while stocks in the 3 other cages were fed following the same daily feeding schedule but only on alternate days. The daily feeding rate recommended was based on our previous studies (De Jesus-Ayson and Borski 2009; De Jesus-Ayson and Borski 2010) where fish can be fed beginning at a rate of 7.5% average body weight versus the standard industry rate of 10% average body weight with little effect on growth in flow-through seawater tanks. Initial body measurements (body weight and body length) were taken at stocking and every two weeks thereafter until harvest in order to monitor growth as well as to adjust feeding ration. Difference in production parameters among treatment groups was analyzed by Students-t-Test.

Table 3 shows the growth of milkfish (changes in average body weight and body length) and Table 4 shows survival (%), the harvested biomass (kg) and estimated value of the production (PhP), the duration of culture, amount of feed consumed during the duration of culture and corresponding cost, and feed conversion ratio of milkfish grown under the different feeding regimen (daily feeding vs. alternate-day feeding). Survival of milkfish was comparable and averaged around 90% in stocks that were fed daily versus those fed on alternate days. Similarly, total harvested biomass of fish on the alternate day and daily feeding groups was similar. Although, not significantly different, the duration of culture for stocks fed on alternate days was slightly longer compared to stocks fed daily. This indicates that fish fed on alternate days grew at a slightly lower rate. The estimated value of the harvested biomass (in PhP) was similar among the two groups. On the other hand, the amount of feed consumed and the corresponding cost of feeds consumed were significantly higher in stocks that were fed daily compared with stocks fed on alternate days. This resulted in savings in feed cost of 32.94% in the alternate-day fed group. Feed conversion ratio (FCR) was higher in the daily fed group (FCR = 3.59) relative to stocks fed on alternate days (FCR = 2.46), but the difference was not statistically significant at the $P < 0.05$ level.

The results of this experiment on intensive culture of milkfish in marine cages are similar to that we previously reported for milkfish culture in brackish water ponds (De Jesus-Ayson and Borski 2009; De Jesus-Ayson and Borski 2010). Insofar as the FCR was lower and savings in feed costs was higher, the response to alternate day feeding in brackish water ponds was even better than that shown here in marine cages. The better response in brackish water ponds may likely be due to natural productivity available to fish as a food source in this environment. Nonetheless, the results shown here demonstrate that alternate day feeding strategies are an effective means to reduce feed costs in

[1] We initially proposed to reduce daily feed ration rate by an additional 1-2% in marine cage culture under this objective. However, we already established that we could reduce feed ration from Phase I of the CRSP project in milkfish held in flow-through seawater tanks (10% down to 7.5% average body weight; Investigation 07SFT03NC). Also, we had just completed studies at the end of Phase I, and found that an alternate day feeding regimen using the reduced feeding rate produced a cost savings of > 50% in milkfish cultured in brackishwater ponds. Therefore, we thought it would be more beneficial to test alternate day feeding in marine cage culture of milkfish using reduced feed ration already established as described herein rather than ascertain if a further reduction in daily feed ration could be beneficial as originally proposed. Indeed, we did find a 32% cost savings in feed when animals are fed on alternate days.

milkfish cultured in the marine environment. In highly intensive mariculture systems, feed cost can constitute up to 80% of production cost, and we show that an alternate day feeding strategy can reduce these costs by as much as 32%. This translates in around a 20-25% cost savings the total variable production costs for producing milkfish even with a slight delay in harvest time.

2. Evaluate the feasibility of co-culture of milkfish with seaweeds and sea cucumber in brackishwater ponds and in marine cages

Brackishwater Ponds

The experiment was designed to test the potential of milkfish, sea cucumber (*Holothuria scabra*) or sandfish and the seaweed, *Gracilariopsis bailinae*, for co-culture in an integrated system. First, preliminary experiments were conducted to test the compatibility of milkfish and sandfish in a co-culture system. A short experiment was conducted using juveniles of milkfish and juvenile sandfish kept together in an aquarium (5L) for one week. Behavior of both the milkfish and sandfish was observed for the duration of the experiment. No mortalities were recorded at the end of the observation period. The second trial was conducted in 250L fiberglass tanks provided with sand substrate, flow-through water and aeration. The experiment consisted of 3 treatments: sandfish and fish, fish only (control) and sandfish only (control). All treatments with fish used fish that were approximately 5 cm in size (8 fish per tank). Three size classes (small, medium and large) and three densities (4, 8 and 12 individuals per tank) of sandfish were tested in combination with fish. Fish were fed up to 10% of body weight of fish per day, spread over 3 rations. The sandfish only controls were fed the same amount as the average of the amount of feed given to the fish only control group. During each sampling (at the start of the experiment and every week for 4 weeks), measurements of fish weight and length, as well as length, width and weight of sandfish were taken. All fish were anaesthetized using 2-phenoxyethanol while sandfish were anaesthetized with 2% menthol. At the end of the experiment, both the fish and sandfish grew in length and body weight confirming the results of the previous experiment, and suggesting that milkfish and sandfish are suitable for polyculture (Zarate et al., unpublished observations).

An experiment on stocking density was also conducted. The experiment consisted of 4 treatments: 50g/m^2, 100g/m^2, 200g/m^2 and 300 g/m^2. Densities of 200g/m^2 and 300g/m^2 showed pronounced decline in growth even after the 1st week. 100g/m^2 and 50g/m^2 showed better overall growth but still showed declining growth after the 3rd week. These results indicate that stocking density of more than 200g/m^2 is not ideal for culture when depending on natural food alone. The decline in growth even for lower densities, further indicate the need for efficient feeding schemes after 2 or 4 weeks of culture of juvenile sandfish (Altamirano et al., unpublished observations).

Preliminary experiments were also conducted in tanks and in the field to test the substrate preference of *Holothuria scabra* in order to determine the range of habitats that will support its growth (Altamirano et al., unpublished observations). Results showed poor performance of sandfish in terms of growth and survival in sandy-muddy and silty-muddy substrates, while high survival were recorded in sandy substrates. A pond with sandy substrate showed best potential for sandfish culture (Altamirano et al., unpublished observations) in consonance with reports from Viet Nam where good production of sandfish cultured in marine ponds previously used for shrimp culture was observed (Nguyen Duy, unpublished observations). We directly stocked sandfish in brackish water milkfish ponds and observed high mortalities within 1 week, suggesting that most brackishwater ponds in the Philippines may not be suitable for sandfish because of the muddy substrate.

Culture of sandfish in cages set in ponds where milkfish are stocked was tested as an alternative. For the trials in brackishwater ponds, six pond compartments with an area of 700 m^2 were stocked with milkfish fingerlings at a stocking density of 0.5 fish/m^2. Milkfish stocks were fed following the recommended daily feeding schedule, but only on alternate days. Initial body measurements (body weight and body length) were taken at stocking and every two weeks thereafter until harvest (in 3 months) in order to monitor growth as well as to adjust feeding ration. Three ponds were stocked with sandfish in cages at a density of 0.2 individuals/m^2. During every other sampling of the milkfish stocks, the sandfish were counted to determine survival over time. The seaweed *Gracilaria bailinae* was used as biofilter and was grown in long lines in the canals surrounding the pond compartments. However, although the seaweeds grown in canals between ponds initially showed good growth, these later died off after alternating days of intense heat followed by days of heavy rains which lowered the salinity in the pond below 25 ppt.

Table 5 shows good survival of sandfish grown in cages set in brackish water ponds. The sandfish grew to an average of 64.39 $\pm$ 11.06 g, 62.58 $\pm$ 11.19 g, 66.0 $\pm$ 10.61 g for replicates 1, 2, and 3, respectively, when the milkfish were harvested. Sandfish grow at much slower rates than milkfish. Thus, in a milkfish + sandfish co-culture system, the sandfish can be grown to market size in the duration of culture of 2 crops of milkfish. In grow out culture in marine ponds as well as in a sea ranch, it takes more than 8 months to grow sandfish to reach a market size of about 300-400g, which can command a good price for the dried product. The sandfish were transferred to another pond with sea bass and pompano for on growing. The presence of sandfish or the sandfish cages likewise did not have any effect on the growth of milkfish as shown by similar trends in growth as indicated by changes in body weight and body length (Table 6).

Table 7 shows that total biomass harvested was comparable in the milkfish only group (90.71 $\pm$ 0.46 kg) and in the milkfish + sandfish group (99.58 $\pm$ 0.62 kg). Likewise, survival rates in the milkfish only group (90.57% $\pm$ 2.08) and milkfish + sandfish group (90.85% $\pm$ 0.62). Survival was generally high in sandfish until the 8th week (about 80%, Table 5) but dropped to about 60% on the 12th week (Table 5) after continuous heavy rains was experienced for several days and salinity fluctuations were recorded. Biomass of sandfish harvested per 2x2x1.5m cage was 5.47 $\pm$ 1.25 kg and can potentially be increased by increasing the number of cages set in the pond compartment.

Marine Cages

The experiment was designed to test the potential of milkfish, sandfish and the seaweed *Kappaphycus alvarezii* for co-culture in an integrated system. Preliminary experiments were designed to identify invertebrate species which may be used in an integrated multitrophic aquaculture (IMTA) system (MJHL Lebata-Ramos, personal communication). Sandfish *Holothuria scabra*, imbao *Anodontia philippiana* and Capiz shell or lampirong *Placuna placenta* were reared in either an open area without cage (no feeding), beneath a fish cage right after harvesting milkfish (no feeding) or beneath a fish cage rearing snapper *Lutjanus argentimaculatus* (with feeding). Growth and survival of sandfish, imbao and lampirong; as well as water quality parameters (temperature, salinity, pH, DO and sulfide) were monitored.

No mortality was observed in sandfish in all treatments until day 7. However, on day 28, 100% mortality was observed in the group reared under the snapper rearing cage, 25% in the group reared beneath a fish cage right after harvesting milkfish *Chanos chanos*, no feeding) and 3.33% in the group reared in an open area without cage (no feeding). Mortalities further increased on week 6 and on the week 8 100% mortality was observed in sandfish in all treatments. Capiz shells or lampirong reared beneath the snapper rearing cage and the milkfish cage right after harvest exhibited mortalities in the weeks following stocking and by week 16, all animals had died. On the other hand, survival of lampirong reared in the open area remained constant from week 8 to 22. In imbao, survival continued to drop in all three treatments and was very low after 22 weeks. Temperature (25.85-29.37°C), salinity (28.04-35.81 ppt), D.O. (0-6.5 ppm) and pH (8.02-8.14) did not significantly differ between treatments. Sulfide was significantly higher in the sediment under the snapper rearing cage (21.68±4.98 µmoles l^{-1}) compared with sulfide levels in sediments under the cage where milkfish used to be cultured (1.42 ± 0.24) and from the open area (1.20 ± 0.08), respectively (Kruska-Wallis Test, H=59.36, p<0.001). An increasing trend in sulfide levels was also observed in the sediment from under the snapper rearing cage. These results suggest that culture of these invertebrates immediately under the cages is not appropriate likely due to elevated sulfide levels in sediment (Lebata-Ramos et al., unpublished observations).

For the trial in marine cages we utilized the experiment outlined from Objective 1 that tested alternate day versus daily feeding on milkfish growout. Milkfish fingerlings were randomly stocked in 6 units 5x5x3m cages at a density of 35 fish/m^3. Milkfish stocks in 3 of the cages were fed daily following the recommended daily feeding schedule, while stocks in the 3 other cages were fed following the recommended daily feeding schedule but only on alternate days. Sandfish were stocked underneath three of the cages and seaweeds were grown in long lines in cages set adjacent to the milkfish cages. However, 100% mortality of sandfish was observed during the 1st sampling (2 weeks). Mortalities were previously thought to be due to predation. However, subsequent trials show that mortalities may be related to inability of sandfish to tolerate increasing levels of sulfide in the sediment under the cages as culture progresses or the high levels of sulfide in sediments in areas that have been used for aquaculture for a sustained period. On the other hand, sandfish seem to thrive in shallower marine pens thus co-culture of milkfish and sandfish in pens will be tested in the future.

Overall, these results show that tolerance of sandfish for sulfide is low. Sandfish is not able to survive for long in areas immediately adjacent to where mariculture activities are ongoing or have been sustained for long periods. Mortality of sandfish is correlated with increases in sulfide concentration in the sediment, which also tends to become more muddy as feed inputs increase with increasing biomass of stocks as occurs with cage culture of milkfish.

Kappaphycus alvarezii grown in cages adjacent to the milkfish cages initially showed good growth but later showed signs of ice-ice disease and exhibited stunting after alternating days of intense heat followed by days of heavy rains. While, the efficiency of *Kappaphycus alvarezii* to absorb excess nutrients from milkfish culture in cages could not be evaluated in the current experiment, better growth of the seaweed stocked in cages adjacent to the milkfish cages mid-way through the milkfish culture was reported (MRJ Luhan et al., unpublished observations). *Kappaphycus* has also been shown to grow better at the SEAFDEC Igang Marine Station when fish production in cages are on-going compared to times in the year when cages have no stocks or after harvest of stocks (Luhan et al., unpublished observations). *Kappaphycus alvarezii* was also reported to absorb excess nutrients from shrimp culture in tanks, resulting in better growth of the seaweed (HS Marcial, unpublished observations).

3. Demonstration of the economic feasibility of integrated culture systems and value-added processing of milkfish through season-long training for community-based livelihood projects

SEAFDEC AQD is currently implementing a project on cage culture of milkfish as a livelihood option for fisherfolks in coastal communities in Guimaras, Philippines under its program on Institutional Capacity Development for Sustainable Aquaculture. The over-all goal is to improve the socioeconomic conditions of fisherfolks in four (4) villages or barangays affected by a major oil spill in 2006 and to support the rehabilitation and ecological recovery program of the Province of Guimaras. The project also aims to develop the fisherfolk organizations (FOs) into viable and profitable business entities and responsible communities in the management of their coastal resources.

During the first phase, SEAFDEC AQD operated a demo farm for milkfish culture in marine cages in the mariculture facilities in its Igang Marine Station in Nueva Valencia, Guimaras. Milkfish farming was introduced as an additional livelihood option. At the same time, a “season-long” training was conducted covering various aspects of milkfish culture from cage design and construction, stocking, feeding management, on-farm feed preparation, disease management, harvesting, post-harvest processing and value adding, as well as marketing. A total of 120 fisherfolk from five FOs in 4 barangays of Nueva Valencia namely San Antonio, Igang, Magamay and Sto. Domingo participated in the different training modules. During the second phase, each of the 5 FOs (Samahan ng mga Mahihirap na Mangingisda ng San Antonio, Samahan ng mga Maliliit na Mangingisda ng San Antonio; Igang Small Fishermen’s Association; Magamay Small Fishermen’s Association, and Sto. Domingo Fisherfolks’ Association) in the 4 barangays was provided operational capital for the construction of a fish cage measuring 10X10X6 m for their culture trial and to serve both as a training/demonstration and production facility for the FOs. Milkfish fingerlings were stocked at 12,000 fishes per cage or at a stocking density of 20 fish/m^3 in December 2008. Culture was done for 6 months and the stocks were harvested from mid-June to July 2009. Income from the production runs was given to the respective FOs. The FOs are now operating their cages on their own, with technical assistance from SEAFDEC AQD.

Table 8 is a sample technical assumptions table for a cage culture operation for milkfish. Tables 9 and 10 show the actual operating expenses and cost and returns for a production run by the group of fisherfolks in Barangay San Antonio, in Nueva Valencia, Guimaras.

The price of milkfish is highly volatile and can change from P60 to P110 ex farm. Since production from the FO's cages is in relatively small volumes, they are highly vulnerable to fluctuation in prices. Although the prevailing price at harvest was relatively good (PhP91.22), there is plenty of room for improvement in terms of survival rate and most especially FCR.

The survival rate obtained for this particular run (86.18%) was below industry average of 90% or better. The FCR obtained was moderately high. Mortalities were experienced when stocks were left unfed for prolonged periods because of unavailability of feeds (mostly due to lack of funds for purchase of feeds). Towards this end of improving production and improving the prospects for the fisherfolks, the concepts of integrated culture and alternate day feeding strategies were introduced by the CRSP-SEAFDEC AQD group in a workshop held in November 2011 in the Nueva Valencia Gym. The Workshop consisted of two parts: a session for men with lectures on updates in milkfish mariculture (alternate day feeding strategies, polyculture systems, specifically milkfish and rabbitfish polyculture, integrated culture, and new feed formulation for milkfish) and a session for women with hands-on activities on seaweeds value addition and product development. There were twenty-five slots each for the sessions for males and females (five participants each from the 5 FOs). Twenty-three women and 17 men attended the workshops. To illustrate the potential of the concept of polyculture being introduced, sample technical assumptions and indicative cost and returns tables were shown for the co-culture of rabbitfish with milkfish and in marine cages (Table 11). Rabbitfish are a low-trophic omnivorous, grazing cultivar that utilizes feed wastage not consumed by milkfish and prevents cage net biofouling. It provides added income for milkfish farmers with no additional feed inputs.

Similar workshops were earlier organized for fish farmers in Roxas, Capiz and Hamtik, Antique (27 participants), and for seaweeds farmers looking for alternative aquaculture ventures in Pandan/Libertad (also in Antique; 28 participants). Additionally, 2 separate workshops were organized for groups of women in 2 barangays (Buyu-an and Parara) in Tigbauan, Iloilo (28 participants) on post-harvest processing and value addition in milkfish (deboning, marinated products, marketing techniques) to enhance income opportunities for fisherfolks. The workshops were met with considerable enthusiasm and our long-term training of the communities continues.

4. Additional Information Dissemination and Other Related Activities

Results of the alternate day feeding strategy have been disseminated in various local, national and regional fora through lectures in seminar workshops, training programs and conferences. In 3-4 May 2011, E.G. de Jesus-Ayson gave a lecture on marine fish culture in the light of environmental degradation and climate change incorporating results of the current milkfish project as well as results of work done in tilapia under the CRSP program during the Seminar Workshop on Fisheries and Aquaculture and Climate Change organized by the Bureau of Fisheries and Aquatic Resources Regional Office 2 in Tuguegarao, Cagayan as part of the activities lined up in celebration of Farmers' and Fisherfolks' month. F.G. Ayson likewise gave a lecture on breeding and seed production for aquaculture in relation to climate change in the same forum. Participants included 150 farmers, fisherfolks and local government officials. Similar lectures were also incorporated in the training course for trainers on marine fish hatchery and culture organized by SEAFDEC AQD for technical staff of all 7 Regional Fisheries Training Centers of the Bureau of Fisheries and Aquatic Resources held from 09 May to 24 June 2011. There were 21 participants in the course. Aside from the RFTC technical staff, there were also private participants from Iran (1) and the Philippines (1). Same lectures were included as well in the curriculum for the regular training course on marine fish hatchery and culture offered by SEAFDEC AQD annually with this year's course running from 20 June to 27 July 2011, with 11 participants from ASEAN member countries.

The alternate day feeding strategy for milkfish and tilapia were likewise included in the thematic paper on Maintaining the Integrity of the Environment Through Responsible Aquaculture and Adaptation to Climate Change presented by EG de Jesus-Ayson during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 - Fish for the People 2020: Adaptation to a Changing Environment (Session on Sustainable Aquaculture Development) held in Bangkok, Thailand from 13-17 June 2011 with over 500 participants from 29 countries.

During the months of April and May, on-the job trainees (OJTs) from various State Colleges and Universities (especially from Mindanao) assigned at the SEAFDEC AQD Marine Fish Hatchery and the Igang Marine Station assisted during samplings and were given informal lectures related to the project. They are as follows: Majella Alarcon, Cherry Lyn Elechicon, TJ Manalo, Girly Olangoy, Rethzel Seberias and Girlie Villanueva (Iloilo State College of Fisheries), Alvin Doroteo (University of Antique-Tibiao Campus) Renato Diaz, Jr. and Brillo Portevilla (Capiz State University), Mechell Advincula, Sitti Amina Hashim and Recil Palosero (Zamboanga State College of Marine Science and Technology), Carlos Angeles, Anwar Lingga and Yusof Saidali (Mindanao State University-Marawi Campus), and Junaldin Ibnosali (Mindanao State University-Tawi-tawi Campus).

CONCLUSIONS

Like that demonstrated for brackishwater ponds, alternate day feeding protocols reduce feed inputs without affecting production of milkfish in intensive marine cage systems. Feed costs were reduced by as much as 32% with an estimated 20-25% reduction in total variable production costs of milkfish in marine cages. This reduced feeding strategy can provide a substantial improvement in income for farmers while reducing environmental impacts associated with excessive nutrient inputs that are known to occur with intensive milkfish culture clusters in coastal environments.

The feasibility of growing sandfish in cages set in brackishwater ponds appears to be a viable alternative to direct stocking of sandfish in ponds which have a silty-muddy type of sediment that results in heavy to total mortalities. Culture of sandfish underneath marine cages or in areas within or immediately adjacent to milkfish mariculture areas was found to be not feasible because of the relatively high levels of sulfide in the sediment which the sandfish are not able to tolerate. However, farming of sandfish in pens or release of sandfish in seagrass beds in shallow areas surrounding mariculture areas may be a feasible alternative.

Although, the feasibility of co-culture of milkfish with seaweeds either in ponds (milkfish with *Gracilaria*) or in marine cages (milkfish with *Kappaphycus*) could not be demonstrated in the present experiments, due to extreme changes in weather, information from the literature as well as results from recent studies have demonstrated the efficiency of these seaweeds to absorb excess nutrients from brackishwater pond and marine cage culture systems, respectively. Hence, there is promise in the use of these seaweeds to mitigate the environmental impacts of milkfish farming.
Information on the benefits of reduced feeding strategies as well as integrated and polyculture culture systems of species that are compatible with milkfish were disseminated through season-long training for community-based livelihood projects through a series of workshops. Skills development workshops were likewise conducted on milkfish processing and value-adding (e.g. deboning, production of flavoured deboned milkfish though smoking and use of various marinades) for women in major milkfish growing areas, as well as processing of seaweeds and preparation of various recipes using seaweeds for women in major seaweeds growing areas, respectively, as potential supplemental livelihood activities. The beneficiaries include 4 fishers' organizations from different coastal villages in Guimaras, fish and seaweeds farmers in Roxas (Capiz), Hamtik and Pandan (Antique) and womenfolk in Tigbauan (Iloilo).

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Table 1. Milkfish production in metric tons (mt), 1996-2010

	1996	2000	2005	2010
Total Aquaculture Production	1,007,678	1,100,902	1,895,847	2,543,720
Total Milkfish Production	150,182	209,994	289,152	349,435
% of total aquaculture production	23	30	22	19
Brackish water ponds, pens	139,372	186,599	219,906	219,443
% of total milkfish production	93	89	76	63
Freshwater cages and pens	10,779	14,523	25,277	42,788
% of total milkfish production	7	7	9	12
Marine Cages and Pens	31	8,872	43,969	87,199
% of total milkfish production	0	4	15	25

Table 2. Feeding rate followed in experiment evaluating daily versus alternate day feeding of milkfish in marine cages.

Average Body Weight (grams)	Feeding Rate (% of Biomass)
< 50	7.5
50 to 100	6
100 to 150	5.5
150 to 200	5
200 to 250	4.5
250 to 300	4
300 to 350	3.5
350 to 400	3
400 to 500	2.5
>500	2

Table 3. Changes in body weight (grams) and body length (cm) of milkfish grown in triplicate in marine cages fed daily or on alternate days only. Values are means ± standard deviation, N=50

Days of Culture	Treatment A (Daily Feeding): Average Body Weight	Treatment A (Daily Feeding): Average Body Length	Treatment B (Alternate-Day Feeding): Average Body Weight	Treatment B (Alternate-Day Feeding): Average Body Length
Stocking	57.72 ± 18.79 68.51 ± 19.38 40.70 ± 8.35	15.14 ± 1.42 15.92 ± 1.40 13.58 ± 0.91	53.26 ± 22.29 56.09 ± 16.45 42.23 ± 11.44	14.71 ± 1.91 15.16 ± 1.43 13.87 ± 1.14
4 weeks	110.12 ± 26.13 107.02 ± 30.92 54.41 ± 13.86	18.67 ± 1.37 18.46 ± 1.68 15.07 ± 1.19	71.50 ± 22.45 86.77 ± 21.11 61.40 ± 14.33	16.27 ± 1.53 17.34 ± 1.35 15.73 ± 1.15
12 weeks	271.74 ± 66.09 237.13 ± 85.51 113.63 ± 30.98	23.13 ± 2.18 23.74 ± 2.50 19.12 ± 1.61	131.94 ± 48.93 162.36 ± 43.99 130.01 ± 34.48	19.82 ± 2.32 21.30 ± 1.85 19.96 ± 1.71
16 weeks	352.81 ± 81.60 399.81 ± 73.64 164.16 ± 36.04	26.95 ± 1.99 28.17 ± 1.97 21.71 ± 1.47	222.99 ± 50.26 245.94 ± 49.51 209.71 ± 63.86	23.49 ± 1.76 24.30 ± 1.65 22.91 ± 2.14
Harvest Time	Day 119 Day 126 207.28 ± 62.85 (Day 146)	 23.11 ± 2.16	Day 138 286.63 ± 86.30 (Day 153) 318.41 ± 61.42 (Day 161)	 25.48 ± 2.32 26.00 ± 1.71

Table 4. Survival (%) and production (kg) of milkfish grown in marine cages fed daily and on alternate days

Parameter	Fed Daily (Control)	Fed on alternate days
Biomass Harvested, Milkfish (kg)	681.5 844.0 585.0 Ave. = 704 ± 76^{a}	724.0 793.5 528.5 Ave. = 682 ± 79^{a}
Estimated Value (PhP)	71,400 86,780 56,220 Ave. = 71,4677 ± 8822^{a}	84,035 79,350 46,750 Ave. = 70,045 ± 11726^{a}
Survival Rate, Milkfish (%)	83.3 101.6 85.8 Ave. = 90.23 ± 5.7^{a}	87.2 89.4 94.5 Ave. = 90.37 ± 2.2^{a}
Days of Culture	119 126 146 Ave. = 130.3 ± 8.1^{a}	138 153 161 Ave. = 150.7 ± 6.7^{a}
Feed Consumed (kg)	2159.6 2667.4 2594.5 Ave. = 2474 ± 159^{a}	1595.7 1914.3 1466.7 Ave. = 1659 ± 133^{b}
Feed Conversion Ratio	3.17 3.16 4.44 Ave. = 3.59 ± 0.43^{a}	2.20 2.41 2.78 Ave. = 2.46 ± 0.17^{a}
Feed Cost (PhP)	53990.0 66685.0 64862.5 Ave. = 61846 ± 3963^{a}	39892.5 47857.5 36667.5 Ave. = 41473 ± 3325^{b}
Savings on Feed Cost (PhP)		**20373.33** **(32.94%)**

Table 5. Survival of sandfish cultured with milkfish in cages in brackish water ponds

Days of Culture	Number of Individuals	Survival Rate (%)
Stocking	140	100
	140	100
	140	100
4 weeks	121	86.43
	113	80.71
	121	86.43
8 weeks	110	78.57
	111	79.28
	112	80.0
12 weeks	57	40.71
	93	66.42
	103	73.57

Table 6. Changes in body weight (grams) and body length (cm) of milkfish cultured with or without sandfish in brackish water ponds. Values are mean ± standard deviation, N = 50.

Days of Culture	Treatment A (w/out sandfish): Average Body Weight	Treatment A (w/out sandfish): Average Body Length	Treatment B (w/ sandfish): Average Body Weight	Treatment B (w/ sandfish): Average Body Length
Stocking	83.49 ± 31.72	17.31 ± 1.95	65.59 ± 26.48	15.95 ± 1.99
	73.88 ± 24.57	16.67 ± 1.72	61.63 ± 27.53	15.32 ± 2.38
	56.26 ± 14.43	15.48 ± 1.25	60.17 ± 25.67	15.59 ± 2.11
4 weeks	144.67 ± 57.32	20.51 ± 2.4	149.63 ± 52.45	20.74 ± 2.28
	124.51 ± 32.99	19.65 ± 2.30	141.58 ± 50 70	20.57 ± 2.18
	109.77 ± 20.21	19.22 ± 1.37	128.99 ± 38.36	20.09 ± 1.59
8 weeks	242.99 ± 50.50	24.69 ± 1.48	238.09 ± 39.59	24.50 ± 1.32
	229.48 ± 44.02	24.18 ± 1.50	259.65 ± 58.84	25.11 ± 1.78
	231.38 ± 30.50	24.40 ± 1.12	254.89 ±48.68	24.87 ± 1.52
12 weeks	315.98 ± 50.64	26.74 ± 1.35	322.30 ± 46.06	26.72 ± 1.23
	282.10 ± 46.92	25.82 ± 1.33	299.16 ± 49.29	26.29 ± 1.34
	290.60 ± 47.95	26.06 ± 1.29	317.96 ± 47.59	26.75 ± 1.27

Table 7. Survival (%) and production (kg) of milkfish cultured with or without sandfish. Values are means ± SE, N = 3.

Parameter	Milkfish only (Control)	Milkfish + Sandfish
Biomass Harvested, Milkfish (kg)	90.71 ± 0.46[a]	99.58 ± 0.62[a]
Survival Rate, Milkfish (%)	90.57 ± 2.08[a]	90.85 ± 0.62[a]
Biomass Harvested, Sandfish (kg)	NA	5.47 ± 1.25
Survival Rate, Sandfish (%)	NA	60.71 ± 14.57

Table 8. A sample technical assumptions table for a milkfish marine cage culture operation

Items	Value
Cage size	10X10X6m
Stocking Density	12,000 pc
Fingerling Size	5-6 inches
Days of Culture	6 months
Average Body Weight	450 grams
Survival Rate	90% (10,800 fish)
FCR (kg feeds/total biomass)	2.8
Total Biomass	4860 kg
Average Selling Price	P100/kg
Gross Income	PhP 486,000

Table 9. Actual operating expenses for a production run by the group of fisherfolks in Barangay San Antonio, in Nueva Valencia, Guimaras

A. Feeds	• **Quantity (kg)**	• **Unit Price**	• **Total Cost**
1. Starter Crumbles	1,500	27.3	40950
2. Starter Pellets	1,875	30.9	57937.5
3. Grower Pellets	5,700	25.9	147630
4. Finisher Pellets	3,750	25.5	95625
Subtotal	**12,825**	•	**342,142.5**
B. Fingerlings	• **12,000**	• 5	• **60,000**
C. Fuel	• **Quantity (Liters)**	• **Unit Price**	• **Total Cost**
1. Diesel Fuel	210	36	7560
2. Motor Oil	2	147	294
Subtotal	**212**	•	**7854**
TOTAL: OPERATING EXPENSES		•	**409,996.50**

Table 10. Costs and returns for a production run by the group of fisherfolks in Barangay San Antonio, in Nueva Valencia, Guimaras

Harvest Date	**Volume (kg)**	**Total Revenue (PhP)**	**Post Harvest Expenses**
June 22, 2009	1180.2	121,616	6289.36
June 30, 2009	2,225.90	187,030	5200
July 5, 2009	550.45	49,020	720
July 7, 2009	562.75	54,572.50	910
TOTAL	4,519.30	412,238.50	13,119.36
Operating Expenses			409,996.50
Overall Expenses (Post Harvest Expenses + Operating Expenses)			423,115.86
Net Income			-10,877.36

Table 11. Technical Assumptions for polyculture of milkfish and rabbitfish demonstrated through a workshop for fisherfolks and their organizations from 4 villages in Nueva Valencia, Guimaras.

Items	**Value**
Cage size	10X10X6m
Stocking Density	12,000 pc (milkfish) 4,000 (rabbitfish)
Fingerling Size	5-6 inches
Days of Culture	6 months
Cost of Fingerlings	P60,000 (milkfish) P20,000 (rabbitfish)
Average Body Weight	437 grams (milkfish) 200 grams (rabbitfish)
Survival Rate	86% (10,341 milkfish) 85% (3,280 rabbitfish)
FCR (kg feeds/total biomass)	2.8 (milkfish)
Total Biomass	4535.7 kg (milkfish) 656 kg (rabbitfish)
Average Selling Price	P100/kg (milkfish) P150/kg (rabbitfish)
Gross Income	P 453,570 (milkfish) P 98,400 (rabbitfish)
Overall Operating Expenses	P 423,115.86 (milkfish) P 20,000 (rabbitfish)
Net Income	**P 108,854.14**