Assessing the Impacts of Sustainable Freshwater Aquaculture and Small-Sized/Low-Value Fisheries Management in the Lower Mekong Basin Region of Cambodia and Vietnam

Food Safety and Value-Added Product Development/Study/09FSV03UC

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INTRODUCTION

Objective: The objective of this study is assess and demonstrate the impact of the investigations in the AquaFish CRSP project "Development of alternatives to the use of freshwater low value fish for aquaculture in the lower Mekong basin of Cambodia and Vietnam: implications for livelihoods, production and markets" on both the private and public sectors and on food security, poverty alleviation, economies, and resource management policies of Cambodia and Vietnam.

Significance: In the Mekong region, many capture fisheries resources have been largely overexploited and, as a result, development of aquaculture has been encouraged to provide the protein, income, employment and export earnings for some countries. Such a development trend implies that sufficient feed for aquaculture production will be available. One source of feed is low value/trash fish (Low value/trash is defined as fish that have a low commercial value by virtue of their low quality, small size or low consumer preference). There is increasing demand and trade in the lower Mekong region of Cambodia and Vietnam for low value/trash fish for (1) local consumption (e.g. fresh, dried); (2) direct feed (e.g. livestock, high value species aquaculture); (3) fish meal production (e.g. poultry, aquaculture); and (4) value-added products (e.g. fish sauce, fermented fish, fish paste, smoked fish).

There is an increasing conflict between the use of small-sized/low value fish for animals/fish and for human consumption. Supplies of small-sized/low value fish are finite, and as indicated by a recent increase in price, i.e. demand is outstripping supply. Small-sized/low value fish are important to the communities and aquaculture, as well as the ecosystems in Cambodia and Vietnam. There is a need to support the development of a policy and management framework to address aquaculture and capture fisheries interactions.

This research project will produce a number of outcomes, including development of a plant based feed for snakehead fish, recommendations to government and the private sector for a sustainable snakehead aquaculture industry, value-added products from small-sized/low value fish such as fish paste and fish sauce, extension/outreach technologies, recommendations for improvements in the marketing system for both capture and culture fish in the region, and recommended policies to improve management of small-sized/low value fish in the Mekong area. These outcomes will impact both the private and public sectors through improvements in technologies, commercialization of new products, sustainable aquatic resource management practices, and policies for aquaculture and capture fisheries. It is expected that the outcomes will have an impact on improving food security, livelihoods, poverty and economic development in the region. Information is needed to demonstrate the importance of this research, the direct and indirect impacts of the research, the communication/dissemination of technologies, and human capacity development.

METHODS

Agricultural research generates many types of outputs. These include technologies embodied in a physical object (e.g., improved feed), management tools and practices, information, and improved human resources. Impact assessment is a process of measuring whether or not research has produced its intended effect—that of meeting development objectives, such as increases in production and income and improvements in the sustainability of production systems. It is important to demonstrate that the changes observed are due to a specific intervention and cannot be accounted for in any other way. The effects can be measured at the household, target population, national, and regional levels. Impact assessment to be undertaken in this investigation will be of two types: ex- post and concurrent. The ex-post assessment refers to the evaluation made upon the completion of a project to determine achievements and to estimate the impact of research. Returns to investment in research and development are typically assessed using the ex-post concept. These studies also help to understand the process of disseminating technology and the constraints to its adoption. Concurrent assessment or evaluation is done to identify the impediments for larger adoption of the research outputs. The purpose of a concurrent evaluation is to correct the gaps and provide feedback for refining and tuning the technology as per the stakeholders' requirements. Often it is known as constraint analysis. Four components determine the adoption of a technology: technology traits (e.g. duration, quality, etc.), policy environment (e.g. price support, procurement, etc.), institutional arrangements (e.g. seed supply sector, credit availability, etc.), and infrastructure (e.g. markets, roads, power, clean water, processing facilities, etc.). Determining constraints for larger adoption forms a part of the impact assessment. Such studies are characterized as part of the early impact assessment. These provide useful information on conditions for larger returns and benefits of research investment. As reported above, this project will produce a number of outcomes. This project will have direct, indirect, and intermediate impacts in the two countries. Direct impact refers to the impact on the welfare of people and the environment as a result of adopting a technology. It is reflected mainly as an increase in productivity, a reduction in per unit cost of production, and/or reduced pressure on expansion into fragile ecosystems because of improvement in technology. Indirect impact includes flow-on impacts to other activities. Intermediate impact refers to increases in the knowledge base that could subsequently have a direct impact.

Through this investigation, students and scientists will be trained in methods to undertake both ex-post and concurrent assessments. Students and scientists will be assigned to each of the six investigations in the project to undertake impact assessment. Impact assessment reports will be prepared and presented.

QUANTIFIED ANTICIPATED BENEFITS

- 12 undergraduate and graduate students in Cambodia and Vietnam will be trained and have experience in undertaking impact assessment of agricultural and resource management research.
- 12 scientists and academics in Cambodia and Vietnam will be trained and have experience in undertaking impact assessment of agricultural and resource management research.
- 10 provincial fisheries officers will be trained and have experience in undertaking impact assessment of agricultural and resource management research.

LITERATURE CITED

Walker T., Maredia M., Kelley T., La Rovere R., Templeton D., Thiele G., and Douthwaite B. 2008. Strategic Guidance for Ex Post Impact Assessment of Agricultural Research. Report prepared for the Standing Panel on Impact Assessment, CGIAR Science Council. Science Council Secretariat: Rome, Italy.

TAC Secretariat, 2000. Impact assessment of agricultural research: context and state of the art. Impact Assessment and Evaluation Group (IAEG) of the Consultative Group on International Agricultural Research (CGIAR), FAO, Rome.

RESULTS

Output 1: Impact Evaluation of Development Projects: Workshops

Conducted by: Dr. Boris E. Bravo-Ureta, Professor of Agricultural and Resources Economics, University of Connecticut

Trip Itinerary for Dr. Bravo-Ureta:
April 26 AM: Depart the US
April 27 PM: Arrive to Ho Chi Minh City and travel to Can Tho
April 28 AM: Arrive in Can Tho and initiate Workshop at Can Tho University in the PM (56 participants)
April 29: Workshop at Can Tho University AM and PM
April 30: Travel to Phnom Penh, Cambodia
May 1 and 2: Holiday
May 3 and 4: Workshop at IFReDI AM and PM (49 participants)
May 5: Travel to Hong Kong
May 6: Travel to Tokyo and on to the US

Workshop Goal: To train participants on impact evaluation (IE) concepts and methodologies so that they are able to design and conduct IE of aquaculture projects.

Workshop Outputs: Trained participants; Draft outline of the IE participants plan to undertake prepared.

Workshop Dates:
Cantho University, Viet Nam, April 28-29, 2011

Phnom Penh, Cambodia, IFReDI Meeting Hall, May 3-4, 2011

Workshop Outline:

DAY 1:
Project Cycle
Performance Indicators, Logical Framework and Results Matrix
Financial and Economic Evaluation of Projects
Financial Criteria for Evaluating Projects
The Basics of Impact Evaluation

DAY 2:
Alternatives Approaches to Impact Evaluation
Data for Impact Evaluation
Evaluation of MARENA: A Case Study

The Way Forward: Work on Teams

Workshop participant list: See Appendix 1

Workshop PowerPoint's: See Appendix 2

Output 2: Assessing the impacts of sustainable freshwater aquaculture development and small-sized/low-value fisheries management in the Lower Mekong basin region of Cambodia and Vietnam

So Nam and Robert Pomeroy

INTRODUCTION

In the Mekong region, many capture fisheries resources have been largely overexploited and, as a result, development of aquaculture has been encouraged to provide the protein, income, employment and export earnings for some countries. Such a development trend implies that sufficient feed for aquaculture production will be available. One source of feed is small-sized/low value fish (species that generally has a maximal total length of equal to or less than 25 cm and a low market value, generally 5 to 10 times lower a market value of big-sized or commercially important fish species) (So Nam et al., 2009a). There is increasing demand and trade in the lower Mekong region of Cambodia and Vietnam for small-sized/low value fish for (1) local consumption (e.g. fresh, dried); (2) direct feed (e.g. livestock, high value species aquaculture); (3) fish meal production (e.g. poultry, aquaculture); and (4) value-added products (e.g. fish sauce, fermented fish, fish paste, smoked fish), which lead to the increase in price over the last decade and the predicted increase in price over the next few years (So Nam & Pomeroy, 2011). Prices also fluctuate with the demand for fish meal in the livestock and aquaculture industry and the availability of raw materials for fish meal production in the Lower Mekong basin (So Nam et al. 2009b; Le Xuan Sinh and Pomeroy, 2009; So Nam et al., 2007; So Nam et al., 2005). Given that aquaculture is predicted to grow while capture fisheries remain stable, it will become increasingly more difficult to meet the demand for small-sized/low value fish for human consumptions.

There is an increasing conflict between the use of small-sized/low value fish for animals/fish and for human consumption in the Lower Mekong River basin (Hap Navy and Pomeroy, 2009). Supplies of small-sized/low value fish are finite, and as indicated by a recent increase in price, i.e. demand is outstripping supply, due to mainly depletion of fish stocks resulting from overfishing, population growth and ecosystem degradation (So Nam et al., 2009a; Le Xuan Sinh and Pomeroy, 2009). 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, etc (Un Sophea et al., 2010; So Nam et al., 2009b; So Nam et al., 2009c). Proponents of this suggest small-sized/low value fish as food for poor domestic consumers is more appropriate than supplying fish meal plants for an export income oriented aquaculture industry, producing high value commodities (Le Xuan Sinh and Pomeroy, 2009). 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 number of people employed in both fishing and aquaculture has this beneficial effect, via income generation, rather than direct food supply.

The government of Cambodia put a ban on snakehead farming in May 2005 and the reasons for this was the potential negative impacts on wild fish populations from wasteful snakehead seed collection and on other fish species diversity, and also potential negative effects on poor consumer groups from decreased availability of small-sized/low valued fish (So Nam et al., 2007). After the ban on snakehead culture in

Cambodia, snakeheads have illegally been imported from the neighboring countries, particularly from Vietnam, to supply high local market demands in Cambodia. Furthermore, the first phase study funded by AquaFish CRSP (07MNE01UC) showed that freshwater small-sized fish have illegally been exported to Vietnam for feeding the significantly and commercially developed snakehead aquaculture in Vietnam and the incentives for choosing snakehead before other fish species by approx. 20,000 fish farmers are strong as it generates more than 10 times higher profits than other fish species (So Nam et al., 2009a). Therefore, the ban does not only result in positive impacts on poor consumer groups from increased availability of freshwater small-sized fish in Cambodia, but also providing negative effects on livelihood of tens of thousands of snakehead farmers who depend on this livelihood for generating household income. In other words, these snakehead fish farmers have lost their important livelihoods and household income. Moreover, the ban also does not provide positive impacts on snakehead wild stocks as fishing pressure on wild snakehead using illegal and destructive fishing gears particularly electro-shockers has been increased for the recent years in order to supply local and external markets (So Nam et al., 2009a).

In Vietnam, snakehead fish have been domesticated for almost two decades in the Mekong Delta (So Nam, 2009). Aquaculture of this domesticated snakehead fish has commonly and wisely been practiced, and recently intensified by using freshwater and marine small-sized fish as direct feed. The snakehead aquaculture production increased from 30,000 ton in 2009 (Le Xuan Sinh and Do Minh Chung, 2009) to 40,000 ton in 2010 (Le Xuan Sinh, pers. comm., 2011). As a result, environmental issue and outbreak of fish disease are the biggest problems, which cause high fish mortality due to poor water quality, and cause decreased income of hundred thousands of snakehead farmers in the Mekong Delta in Vietnam. As intensive snakehead aquaculture has been developed, many kinds of pathogens may cause serious diseases.

The recent studies of AquaFish CRSP produced a number of outcomes, including development of a plant based feed for snakehead fish (Tran Thi Thanh Hien and Bengtson , 2009; Tran Thi Thanh Hien and Bengtson 2011), recommendations to government and the private sector for a sustainable snakehead aquaculture industry (Tran Thi Thanh Hien and Bengtson 2011, So Nam et al., 2011; Pham Minh Duc et al., 2011), value-added products from small-sized/low value fish such as fish paste and fish sauce (Kao Sochivi and Pomeroy, 2011; Un Sophea et al., 2010; So Nam et al., 2009bc) , extension/outreach technologies (Pham Minh Duc et al., 2011; So Nam et al., 2009a), recommendations for improvements in the marketing system for both capture and culture fish in the region (Le Xuan Sinh et al., 2011; Hap Navy et al., 2011; Un Sophea et al., 2010; So Nam et al., 2009c), and recommended policies to improve management of small-sized/low value fish in the Mekong area (So Nam & Pomeroy, 2011). These outcomes have impacted or are impacting both the private and public sectors through improvements in technologies, commercialization of new products, sustainable aquatic resource management practices, and policies for aquaculture and capture fisheries.

OBJECTIVE

The specific objective of this study is to assess the potential impacts of the two investigations: (1) 09IND02UC: Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia and Vietnam and (2) 09MNE04UC: Developing management recommendations for freshwater small-sized/low value fish in the lower Mekong region of Cambodia and Vietnam. The impact assessment is the potential for (1) opening up the snakehead aquaculture again in Cambodia; (2) sustaining the development of snakehead aquaculture in Vietnam; (3) improving the management of small-sized fish in the Lower Mekong basin.

METHODOLOGY

This study was primarily a desk analysis of research findings, followed by a series of consultations and training workshops with all relevant government and non-government organizations, research and academic institutions, and the private sector on (1) Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia and Vietnam; (2) Developing management recommendations for freshwater small-sized/low value fish in the Lower Mekong region of Cambodia and Vietnam; (3) Impact evaluation of development project in order to assess the potential impacts of the study.

RESULTS

Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia and Vietnam
The three specific objectives: (1) to domesticate breeding of wild snakehead to address the snakehead banning issue in Cambodia in order to lift the ban on snakehead culture in Cambodia; (2) to study environment impacts, fish diseases and biosecurity of snakehead farming in Vietnam; and (3) to provide recommendations for policy and best practices development of snakehead farming were successfully addressed and achieved by the following summary of research findings.

In Cambodia, the present investigation demonstrated that 84 breeders of the wild striped snakehead Channa striata can successfully be developed, mature and semi-artificially induced spawning using HCG at doses of 1,000 $IU.kg^{-1}$ for female fish and 3,500 $IU.kg^{-1}$ for male fish at the hatchery of Freshwater Aquaculture Research and Development Center (FARDeC). The male fish receive 2-3 injections within 2-3 days before the female fish, which is received only 1 injection. With this optimal HCG doses, the spawning success is 100%; spawning time after the last injection of female and male fish is 9 hours; number of eggs spawned per kg female is 32,000; the fertilization rate is 87%; hatching rate is 73%; and the larval production and survival rate is 21,000 larvae per kg female and 72%, respectively.

The striped snakehead Channa straita aging 30 days old after hatch can gradually and successful accept formulated feed in replacement of small-sized fish in the rate of 10% every three days for a period of 30 days of feeding, and then be successfully grown out with a complete 40% crude protein pellet feed for a period of ten months to achieve a final weight of 314 $g.fish^{-1}$, a survival rate of 56%, and a FCR of 1.68. The F_1 broodstocks which can accept formulated or pellet feed are available for future domestication breeding and weaning at FARDeC. This has very important implications for protecting freshwater small-sized fish, which are usually fed to snakehead.

In the future, if the above technologies are successfully trialed in fields with snakehead farmers and widely adopted by snakehead farmers in Cambodia, there will be a great potential for opening up the snakehead aquaculture in Cambodia.

In Vietnam, The potential pathogens, including 32 genera of parasites, 4 genera of fungi and five genera of bacteria infesting snakehead fingerlings and grown-out snakehead in An Giang and Dong Thap provinces, Mekong delta of Vietnam are successfully identified, classified and documented.

In Vietnam, the main water quality parameters are successfully recorded in this study. The results of this study illustrated that temperature and pH value in snakehead cultured ponds in An Giang and Dong Thap provinces are not considerably varied. In the whole cultured period, the concentration of N-NH4+ and N-NO2- increases, while the concentration of N-NO3- reduces in the posterior end.

Improvement of snakehead culture skills is mostly from the gain of experiences and participation in trainings provided by provincial fisheries officers. Water quality management was applied by the majority of household (75%) such as the use of test kits. Most of the snakehead farming household (70%) complain parasite infection to their snakehead fish. Therefore, parasite infection is the key issue in snakehead farming in the Mekong Delta of Vietnam.

The potential pathogens, including parasites, fungi and bacteria infesting snakehead fingerlings and cultured snakehead in An Giang and Dong Thap provinces, Vietnam are successfully identified, classified and documented. Nine genera of parasites were identified from 142 samples of snakehead fingerlings in nursery ponds, including of Dactylogyrus, Trichodina, Epistylis, Trianchoratus, Chilodonella, Proteocephalus, Spinitectus, Pallisentis. Trichodina have the highest prevalence infection of 93.7%, while Proteocephalus and Henneguya had lowest prevalence infection of 3.52% and intensity of lowest (+). There were 23 genera of parasites identified from cultured snakehead sampled from growth-out ponds in An Giang and Dong Thap provinces. Of which, 6 new genera are found in cultured snakehead, comprising of Henneguya, Chilodonella, Epistylis, Tripartiella, Gnathostoma and Capillaria. Gyrodactylus is noted with the highest prevalence infection of 72.6% and the lowest is found in Lamproglena (0.7%).

Achlya sp. was isolated from snakehead fingerlings in nursery ponds in the first and second month of culture period. The frequency of appearance is 46% in the whole isolated fungi recorded. The optimum temperature for Achlya sp. VN1101 growth was 28oC. The results demonstrated that Achlya sp. VN1101 is main pathogen causing cotton-like in snakehead fingerlings revealed by pathogenicity experiment. There are 4 genera of fungi isolated from cultured snakehead in grow-out ponds in An Giang and Dong Thap provinces, including Acremonium (frequency of appearance is 35.7%), Geotrichum (28.6%), Achlya (21.4%) and Fusarium (14.3%). The fungi are recognized in the first three months of culture period, and Achlya is only noted in the first month of the cultured period when the fish is 96.6-165 g in weight.

81 bacterial strains are indentified from unhealthy fish. Bacterial strains are grouped to 5 genera based on morphological and biochemical characteristics, comprising of Aeromonas (frequency of appearance of 38.3%), Edwardsiella (17.3%), Vibrio (16.0%), Streptococcus (14.%) and Pseudomonas (13.6%). Of which, Edwardsiella was only isolated in the second month of the cultured period when fish was 175.7-295.3 g in weight, and Streptococcus was also detected in the fifth cultured month when fish was 620.4-850 g in weight. Besides, Aeromonas hydrophila was believed as a primary pathogen to snakehead fingerlings revealed by pathogenicity experiment. The clinical signs were observed, consisting of haemorrhage in fish body and fins, red spot in ventral area, and scales damage and loss.

Based the above research results an outreach document "Atlas of pathogens of the striped snakehead *Channa striata*" is developed and disseminated to all provincial fisheries extension officers and some snakehead fish farmers in An Giang, Dong Thap and Can Though provinces of the Mekong Delta, Vietnam for the purpose of reducing environment impact and outbreaks fish diseases, and for increasing biosecurity of snakehead farming.

The quantifiable economic benefits of this investigation are as follows:

- In Cambodia, approx. 20,000 farmers who used to produce 11,000 ton of snakehead will benefit from this Investigation by restarting their snakehead culture after the ban on snakehead culture in Cambodia by future adoption of breeding, weaning and growth-out technologies of snakehead fish developed by this investigation.
- In Vietnam, at least 30,000 farmers who are producing over 40,000 ton of snakehead will increase their fish production by increasing fish survival rate from 50% to 90% by future adoption of fish disease prevention and treatment proposed by this investigation
- The above research outputs have been informed to 40 scientists and researchers, 100 government fisheries officers/managers and policy makers, 50 aquaculture extension workers, 30 NGO staff, 20 aquaculture companies and 100 fish farmers working on snakehead aquaculture in Cambodia and Vietnam at the project inception workshops, final project stakeholder consultation

workshops, national aquaculture and fisheries symposiums, and aquaculture trainings for fish farmers in Cambodia and Vietnam.

- 500 copies of a Photo Atlas of pathogens of the striped snakehead *Channa striata* were disseminated to the above stakeholders.
- Six students, two in Cambodia and four in Vietnam, were supported by the project and graduated, and they are now working for private aquaculture companies and non-government organizations.
- More than 100,000 snakehead farmers in Vietnam will operate environmentally friendly, healthy and sustainable snakehead aquaculture after adoption of improved knowledge on fish health management and bio-security.
- At least 1,000,000 indirect beneficiaries in Cambodian and Vietnamese who consume snakehead fish in their protein diets.

Developing management recommendations for freshwater small-sized/low value fish in the Lower Mekong region of Cambodia and Vietnam

The objective of this study is to develop management recommendations for freshwater small-sized/low value fish in the Lower Mekong region of Cambodia and Vietnam in order to reestablish stocks to support food security and poverty alleviation.

This specific objective was achieved by the following management recommendations for sustaining small-sized fishery resources in the Lower Mekong basin.

1. The capture fisheries of Lower Mekong River basin in Cambodia and Vietnam are overfished due to illegal and high fishing pressures, population growth, and floodplain or wetland ecosystem degradation. Therefore the freshwater small-sized fish production, which contribute more than 80% to the total freshwater captured fisheries in the Lower Mekong River basin of Cambodia and Vietnam and are used and important for human food consumption, fish, including snakehead fish, and other animal feeds, and aquatic or wetland ecosystems, are scarce or limited, although the biodiversity of freshwater small-sized fish species is rich (at least 200 species). Capture fisheries are not the major threat to biodiversity in rivers – aquatic environmental or ecosystem degradation is.
2. Understanding the role of ecosystem variability (including hydrology) in sustaining the Lower Mekong's rich biodiversity is crucial. Development activities in a river system almost always result in the simplification, or even obliteration, of ecosystem diversity. These disturbances appear to be by far the greatest threat to sustaining aquatic biological resources in Lower Mekong River basin.
3. The important role that river floodplain fisheries play in maintaining aquatic biodiversity must be promoted more widely. All sectors should cooperate in integrated water resources management (i.e. IWRM approach).
4. The waters of the Mekong and its tributaries could be put to many uses: irrigated agriculture, potable domestic supply, hydroelectricity production, navigation and fisheries. In Cambodia, fisheries production is primarily from the wild capture fishery. Developments in other sectors will become increasingly common in the future and the wild fishery is likely to decline as a consequence. Actions to mitigate and manage the impacts of water management projects will minimize this decline; such actions depend upon an effective engagement of fisheries managers with planners in other sectors. Only through this approach can we have truly sustainable development for the people using the resources of the Mekong.
5. Emphasizing the importance of fisheries of small-sized fish species to livelihoods and food security provides the strongest and most relevant argument for improved management of the aquatic environment.
6. Fisheries activities can have negative impacts upon biodiversity. Improved management of law and regulation enforcement, and exploitation, by moderation the use of unsustainable fishing practices such electro fishing, small mesh size net fishing, brush-park fishing and pumping fishing method,

should centre on the promotion of co-management approaches to decentralization of fisheries management (i.e. dialogue between local resource users, government authorities, scientists and other stakeholders on management needs and methods in order to reduce the impacts of illegal fishing and overfishing.

7. Management initiatives need to be prioritized and adaptive, focusing on those species and habitats under greatest threat and basing on scientific research and monitoring data and local ecological knowledge. Recent experience has shown a high level of agreement between local ecological knowledge and fisheries science.
8. The use of local ecological knowledge as both a research tool and a mechanism for improving participation in management should be promoted more widely. There should be increased recognition of the importance of this knowledge base for biodiversity-related subjects.
9. The fishing "lot" system of floodplain fisheries and river dai fishery in Cambodia should be properly and scientifically evaluated to determine if it is an effective tool for sustaining biodiversity. Studies should include consideration of whether social equity and sustaining biodiversity are necessarily mutually exclusive. There is considerable interest internationally in this system as a way of improving environmental management.
10. Freshwater fish protected areas, dry season refuge ponds, and channel for migrating fish on floodplains should be maintained or scientifically identified and established in fishing “lot” areas, community fisheries areas, and floodplain rice-fields, and an adaptive plan for managing these protected areas should be developed and implemented to protect and enhance stocks or populations of this rich biodiversity.
11. Development planning should recognize the value of fisheries and their importance in the livelihoods of Cambodian and Vietnamese people.
12. Environmental Impact Assessments should consider all options for development, as well as the costs and benefits of competing uses of water.
13. Plans for water management projects should include consideration of sustaining, and where possible, increasing fish production.
14. The main elements of the flooding cycle and important fish habitats should be maintained where possible; if water management projects are designed to reduce flood levels then the consequences for fisheries production should be appraised and appropriate substitutes for livelihoods and income for those affected should be available.
15. Any evaluation of dams proposed for the Mekong mainstream and major tributaries should consider the consequences for fish migrations and floodplain production downstream, and should recognize that impacts could not be fully mitigated.
16. Mitigation measures should be incorporated in the design and operation of dams, including low-level weirs; these could include fish passes, maintenance of riparian flows, re-regulation of discharges and measures to improve water quality.
17. Dialogue should be maintained between LMB countries on mitigating transboundary impacts from water management projects, fishing activities and exotic species, both up-and downstream of Cambodia and Vietnam. Where migration routes cross national borders, fish stock management becomes a trans-boundary issue and requires international collaboration.
18. The emphasis might be on developing appropriate procedures for cooperation at the international level in harmony with national and local management initiatives. The best opportunities are with the high profile migratory fish species and the vulnerable habitats such as the flooded forests and the deep pools where a consensus already exists on the need for action.
19. More information is required on the ecology (e.g. migration and spawning sites and behaviors), population genetics (e.g. stocks), and value and importance for livelihoods of the Lower Mekong River fisheries of Cambodia and Vietnam. But enough is known to provide clear directions for management of theses freshwater fisheries. It is time to adopt an integrated approach to conserving and enhancing fisheries for the continuing well-being of Cambodia and Vietnam and their neighboring countries.

20. Macro-habitat requirements are known for a few species in broad categories such as floodplain habitats and deep pools. However, micro-habitat requirements are unknown for most species. For example, even if it is known that a certain species lives in deep pool habitats during the dry season, the habitat features that the species require within the deep pool (type of substrate, vegetation, depth, slopes, current etc.) are unknown. Such micro-habitat requirements determine types of pools certain fishes prefer and indirectly determine other ecological characteristics including migration patterns.
21. Feeding biology for most species is related to the micro-habitat issue since availability of food (for example on the floodplain) determines the preferred floodplain micro-habitat.
22. A more attainable short-term goal is to promote changes to land classification systems, which are the basis for both natural resources planning and asset allocation. The current system suffers from a bias toward dry-season agricultural uses of land. It appears that legal systems are ill equipped to deal with assets undergoing dynamic changes especially for seasonal wetlands. Wetlands rarely have any legal status and are usually regarded as open access areas during the flood season. Converting these areas to agricultural use would not necessarily be more efficient biologically but it would enhance people's security of access and ownership. The legal status of wetlands and related institutional limitations are already recognized as constraints in achieving sustainability of fisheries and other natural resources.
23. Aquaculture production, including snakehead fish over nearly past ten years in Cambodia and Vietnam has rapidly expanded and continued expansion of aquaculture will contribute significantly to meeting the anticipated demand for fish products in the coming decades, although the difficulties in meeting anticipated demand are considerable.
24. Aquaculture, capture fisheries and reservoir management should be considered as a holistic system. Concentrating policy and development efforts towards aquaculture, as an 'easy option' for fish production, without taking proper care of the wild fisheries could result in a dramatic loss of wild fisheries resources, with food security implications for the Lower Mekong Basin of Cambodia and Vietnam, particularly for poor people. Similarly, aquaculture and fisheries are strongly influenced by the development of other sectors. A balanced approach to fisheries development is required.
25. Aquaculture can have the greatest impact on rural households in areas with food insecurity and limited wild fish supplies. The approach to supporting food security and livelihoods should be based on identifying these areas and supporting local area development, which may be aquaculture or wild fisheries activities or a combination of both. Therefore establishment and implementation of an action plan for development of aquaculture of indigenous Mekong fish species, including genetic knowledge and information, which are less dependent on freshwater small-sized fish as direct feed (e.g. omnivorous and herbivorous fish species), should be encouraged and supported by public and private sector and non government or civil society organizations.
26. Further research and development of formulated diets and domestication breeding, weaning and growth-out technologies for sustaining snakehead aquaculture in Cambodia and Vietnam should be a joint effort and support among public and private sectors, research and academic institutions, non-government organizations and snakehead farmers. The demand of freshwater small-sized fish is outstripping supply, so these fish should be important for local communities' food consumption and for maintaining aquatic biodiversity and ecosystems.
27. Golden snails are so abundant in all rice fields of the Mekong Delta and harmful to rice production. Research on snakehead aquaculture using golden snails as a source of protein should be encourages and supported. This will have very important implications for reducing environmental and economical impacts caused by golden snails.
28. There are several constraints to sustainable development of snakehead aquaculture, especially in Cambodia, that will have to be addressed. Many of these are institutional rather than technical. The existing capacity and resources of government institutions for participatory extension and research is relatively weak and manpower is limited. Therefore, capacity building is required to support this approach. New partnerships going beyond traditional aquaculture extension are needed. The policies to support an integrated approach to aquaculture are not yet in place. There is a need to develop enabling policies to support the approach, but this will take time.

29. Diversification of rice farming systems using omnivorous or herbivorous indigenous Mekong fish species and integrated pest management, including economics and livelihood impacts of farming options and practices.
30. Reducing risks to rural livelihoods from aquatic animal diseases is one of the priority areas for sustaining snakehead aquaculture in Cambodia and Vietnam.
31. An efficient low-cost contingency plan for fish health management may also be established on a catchment as well as transboundary basis. Plans should be prepared for the containment and treatment of fish disease including the prevention of trade in live fish and movement of fry, fingerlings and breeders from a catchment area or cross border or transboundary area where an outbreak has been detected.
32. Further maximization of the utilization of freshwater small-sized fish for human Consumption through improving quality standard and safety with appropriate value added product development (e.g. fermented fish paste in Cambodia and fish sauce in Vietnam).
33. More information is needed on the trade of freshwater small-size fish and fish products, including snakehead fish within the basin and exports and imports to and from the basin.

POTENTIAL IMPACT ASSESSMENT

Based the above summary of research findings, in Cambodia, after the snakehead ban, Approx. 20,000 households utilized 55,000 ton of small-sized freshwater fish as feed to produce 11,000 ton of snakehead and earned a total income of US$ 22 million per year or an average of US$ 1,100/household/year lost their job and income. If future adoption of breeding, weaning and growth-out technologies of snakehead fish using formulated feed developed by this investigation is taken, (1) these 20,000 snakehead culture households can restart this business and earn this income; (2) 55,000 ton of small-sized freshwater fish can be utilized for human consumption as these farmers will utilize formulated diets for snakehead farming leading to improvement of water quality and biosecurity in snakehead farms for not only in Cambodia but also in Vietnam; (3) Approx. 16 million of wild collected fingerling can be wildly grown to breeder stage for the sustainable development and conservation of wild stocks of snakehead fish due to the dependence on hatchery snakehead fingerling of at least 16 million per year to produce the same production level of 11,000 ton as in 2004/05, before the ban on snakehead culture in Cambodia; and (4) fishing pressures on freshwater small-sized fish will decrease, and implications for sustainable utilization and management of these invaluable resources if the above management recommendations for freshwater small-sized/low value fish in the Lower Mekong region of Cambodia and Vietnam are implemented.

Based on the above summary of research findings, in Vietnam, snakehead farmers produced 40,000 ton of snakehead in 2010 by using approx. 30,000 ton of freshwater small-sized fish, 105,000 ton of marine small-sized fish and 45,000 ton of fish wastes from Pangasius fillet processing plants, with the survival rate of 40%-50%. If the farmers in the Mekong Delta of Vietnam potentially adopt the growth out technology of snakehead by using formulated diets and apply for good fish health management and biosecurity practices, the survival rate will increase up to 90%, leading an increase of snakehead production from 40,000 ton to 72,000-90,000 ton. Therefore the income of every snakehead farming household will be increased by 40-50%. Finally 30,000 ton of freshwater small-sized fish can be used for human consumption, implying for an increase in food security for the rural poor.

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Output 3: Trip Report for Snakehead study in Vietnam (May 28, 2011 - August 4, 2011)

Justin Grimm-Greenblatt[2]

I chose to conduct my research project in Can Tho University in Can Tho, Vietnam. This opportunity was provided to me through support from Robert Pomeroy PhD., Dorothy Goodwin International Experience Fund, and AquaFish CRSP. The research I was involved in was part of a larger project called AquaFish Collaborative Research Support Project (CRSP). It is currently being conducted in collaboration with the University of Connecticut (USA), Inland Fisheries Research and Development (Cambodia), and Can Tho University (Vietnam) and with the respective lead investigators Robert Pomeroy, So Nam (Cambodia), and Le Xuan Sinh and Tran Thi Thanh Hein (Vietnam). The objectives the project is as follows:

1. To domesticate wild snakehead to address the snakehead banning issue in Cambodia in order to lift the ban on snakehead culture in Cambodia
2. To study environment impacts, fish disease and biosecurity of snakehead farming in Vietnam
3. To provide recommendations for policy and best practices development of snakehead farming.

The project focuses on both the aquaculture of carnivorous fish and the management of lower value/trash fish by addressing the uses and bio-ecological characteristics of low value/trash fish and exploring alternative feeds and feed technology for freshwater aquaculture. By understanding the social, economic, and environmental/natural resource needs and implications of freshwater aquaculture, this project hopes to create sustainable freshwater aquaculture development in the Lower MKD of Cambodia and Vietnam. This project takes into account capture and culture fisheries and how they play a significant role in food security, poverty alleviation, and economies

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within Cambodia and Vietnam. It also addresses the combined management of capture and culture fisheries and the competition and conflict that has been increasing between the uses of low value/trash fish for feed and human consumption. The first phase of this project has already accomplished developing weaning methods so small, hatchery-reared snakehead can quickly adapt to pelleted diets; it was determined that snakehead survive as well on pelleted diets that have as much as 50% of the fish meal replaced with soybean meal. Issues relating to the processing of to low value fish and value added product development were determined. Policies and strategies were recommended for market and trade, which helped maintain high quality, safe, and nutritious low value fish products for local and international trade.

While in Vietnam I worked under the direct mentorship of Le Xuan Sinh, PhD., a faculty member of the Fishery Economics and Management Department of the College of Fisheries and Aquaculture of Can Tho University on two projects that are still in progress. These projects are a value chain analysis of the snakehead and a cost benefit analysis of snakehead.

PEOPLE

While working at Can Tho University in the Fishery Economics and Management Department, I worked most closely with Sinh, Mr. Hein, and Ms. Quyen. Sinh, is the Vice Head of the Fisheries Economic and Management Department. We would frequently meet over breakfast to discuss the scope of the projects and what the next steps to be taken should be.

Mr. Hein was the first person I met when I arrived in Vietnam at the airport. I worked with Hein on the cost benefit analysis and he showed me how to use a program called SPSS, a statistical program I had not yet learned. He frequently took me out for lunch during the work week and helped me find my way around. Hein often helped me organize side trips for the weekends as well.

Quyen, a graduate who is now employed by the Fisheries Economic and Management Department and is being mentored by Professor Sinh, first showed me around the campus and the city so I could get settled in. We frequently worked together on projects and I helped her with her scientific writing skills in English and speaking. I am continuing to help her with the food fish consumption project she is currently working on.

Another person I became familiar with in the Department was the Vice Dean of Faculty of the Fishery and Aquaculture Department, Tran Thi Thanh Hein. She told me how she worked extensively with David Bengston, PhD. from the University of Rhode Island to develop a formulated pelleted feed. This pelleted feed relies on soy protein instead of low value trash fish for its protein content. High protein content is required for snakehead feed. However, many people rely on low value trash fish for food, which is most often used as the protein source for snakehead. But, the new formulated feed could reduce the fishing pressure on these low value fish that so many people rely on for a food source.

I also met with Dr. So Nam while in Can Tho, a director and researcher from the Inland Fisheries Research and Development (IFREDI) in Cambodia. He told me how he is conducting research on snakehead in Cambodia. It is currently illegal to grow snakehead in Cambodia because it requires extensive low value trash fish for feed. So Nam hopes that if the project is a success in Vietnam, the new feed technology can be transferred to Cambodia and reopen a fishery, which can offer significant incomes to people.

Figure 1: Myself, Professor Sinh, Ms. Fung, and Ms Quyen.
Figure 2: Fisheries Department and myself barbequing seafood at the university.

RESEARCH IN VIETNAM: VALUE CHAIN ANALYSIS

In order to evaluate the industry we will utilized a value chain, which is defined as "the full range of activities which are required to bring a product or service from conception, through the intermediary phases of production, delivery to final consumers, and final disposal after use" as stated in Kaplinsky and Morris's (2001) Handbook for Value Chain Research. This analysis allowed us to identify barriers of entry along the chain and analyze the interactions between actors in each step of production. Value chains have been used throughout the last two decades, it is a new approach for analyzing global fishery production at a micro-industry level (Pomeroy, 2009). It has already been used by Loc et al (2009) in the MKD of Vietnam and Cambodia to study Pangiasius catfish and Ca Linh. There have been several others.

The objectives of the value chain analysis on snakehead included describing and analyzing the situation of the actors participating in the cultured snakehead industry, analyzing the cost-benefit distribution of the snakehead value chain, and proposing improvements for upgrading this chain so that it is sustainable in the long term. It also identified major actors involved in the chain of cultured snakehead in the Mekong Delta, distinguished the profit distribution of the identified actors, and offered suggestions and ideas for policies that would nurture long-term development of snakehead culture in Vietnam.

My involvement in the value chain analysis project was to review the results from the data collections and help write a publishable paper with Sinh. I was previously given a value chain analysis done on pangasius catfish to better understand how value chains are conducted. Then I was given rough draft of a conference paper outlining the value chain of hard clam and black tiger shrimp to correct and further my familiarity with value chains. This paper was presented to the Tra Vinh's People Committee Council in Tra Vinh. This was a great way to become familiar with this type of analysis before I worked on snakehead.

I then began work on the value chain analysis for snakehead. This value chain analysis identified the five major actors to be farmers, wholesalers, processors, and retailers along with two support groups that included market managers and sector managers. It was also found that the distribution of profit among actors was distributed unequally. Difficulties involved in snakehead culture were observed to be that farmers frequently used live feed, there was a lack of planning in the development of this culture making it difficult to manage, and it was mainly sold domestically. To better aid the development of this culture along with its disadvantages, we recommended that there needs to be better management of capture fisheries, which is consumed by snakehead culture, providing more technical training involving this culture and improving the supply of pelleted feeds. We also thought programs to better facilitate new markets especially export markets would be extremely beneficial.

ECONOMIC ANALYSIS

The aim of producing a cost benefit analysis on the use of the formulated pellet feed was to measure whether the intended effect on the economic development occurred and by how much. Since the overall adoption of the pelleted feed is still an ongoing project this part of the CRSP project is a concurrent assessment, which will evaluate what impediments are occurring that would prevent a larger adoption of the new feed. Some of these constraints can be accounted for by technology traits, policy environment, institutional arrangements, and infrastructure.

Prior to going to Vietnam, I worked with Boris Bravo-Ureta, PhD. on setting up a training lecture that he would give in Vietnam and Cambodia, which taught 12 undergraduates and graduates, 12 scientists and academics, and 10 provincial fisheries officers how to undertake an impact assessment. I helped Professor Bravo-Ureta set up a cost benefit analysis template on Microsoft Excel and a lecture on Microsoft PowerPoint using the data found in The financial feasibility of small-scale grouper aquaculture in the Philippines by Pomeroy et al. (2001) published in Aquaculture Economics & Management. This provided me with the pre-training I needed to help facilitate the impact assessment in Vietnam comparing the costs and benefits of utilizing the new formulated feed versus low value trash fish for culturing snakehead. Unfortunately the data collected from farms that cultured snakehead was provided to me until later than expected during my stay in Vietnam. Therefore, I am currently outlining the best way to organize this data. The data was provided to me on SPSS and I made sure to take the time while in Vietnam to become more familiar with this program as I will be utilizing both SPSS and Microsoft Excel in this analysis. As previously mentioned, Mr. Hein was a life saver because he spent a whole day with me to show me how to use SPSS.

CONFERENCE

Professor Sinh also had me sit in on conference that was led by Flavio Corsin of International Collaborating Center for Aquaculture and Fisheries Sustainability (ICAFIS) where I was introduced to the challenges involved in developing and managing aquaculture, specifically pangasius catfish. A mixture of people with careers as scientists, technicians, and employees of non-profits brainstormed more efficient ways of measuring aquaculture's impact on the environment. One of the ideas I mentioned to Flavio and the group was the lack of analysis or incorporation of already established data on the negative externalities involved in the production of inputs in aquaculture. These may include the production of medicines, transportation of inputs, catching fish in Peru for fishmeal etc.

Figure 3: This is a picture of myself listening to Flavio Corsin lecture us at the workshop on measuring the regional impact of aquaculture.

HANDS-ON LEARNING

I had the chance to visit one of the hatcheries and grow out farm that was interviewed for the value chain analysis only a few hours outside Can Tho. It was called Nhu Y in Phu Tho village, tam Nong district, Dong Thap province. The owners of the hatchery told me they had begun to use the pelleted feed and told me of how they needed to start the fingerlings on trash fish and then wean them off it onto the pelleted feed. They stated that they frequently utilized freshwater trash fish instead of saltwater trash fish because it was usually cheaper and in better condition since it was caught more locally. I found this interesting because one of the key points that Dr. Hein mention in her paper entitled, The replacement of fish meal protein by soybean meal protein with or without phytase supplementation in snakehead (*Channa striata*) diets, which was published in the Journal of Can Tho University, was how salt water trash fish better helped promote growth but I guess the benefit was outweighed by the cost in this specific case.


Figure 4: Nhu Y hatchery/grow-out farm with different hapas that separated different size snakeheads that were being fed pelleted feed.

Figure 5: Quyen, Mr. Hein, and myself speaking with the family who runs the hatchery/grow out farm.

After visiting the hatchery we visited one of the markets and asked the merchants about their snakehead products. They sold whole, fermented, and dried snakehead. The most expensive was the fermented snakehead and the least expensive was the whole snakehead. At this market they sold a variety of live food which included rats, birds, snakes, fish, shrimp, and much more. Professor Sinh translated conversations he had with merchants for me that involved information about the quality, location, and price of different snakehead products being sold.









Figure 6: Boats that transported goods including snakehead to market.
Figure 7: Me behind snakehead being sold.
Figure 8: Dried snakehead.
Figure 9: Fermented snakehead.
Figure 10: Shrimp.
Figure 11 and 12: Birds being sold.
Figure 13: Ducklings for sale.
Figure 14: Rats for sale.)

Since my ultimate goal after finishing graduate school is to involve myself in the aquaculture industry I thought it would be appropriate to become more familiar with the techniques used for culturing fish. This is one of the reasons I chose to go to Vietnam. I was fortunate enough to also obtain hands on training while in Can Tho since the university had its own aquaculture facility that bred, nursed, and grew out fish.

A variety of fish were cultured on campus including snakehead. I observed and participated in the culturing of the carp shown in the pictures below. Once the brood stock was netted from one of the ponds, they were separated by sex. Besides observing the brood sac on females, another way to sex these fish is pretty neat. If you pull on the pectoral fin of a male, their tail will move. After being sexed, the females of were given a dose of LHRA to induce egg deposition. Once eggs were extracted, they were mixed with the extracted sperm from the males. The fertilized eggs were then placed in containers with constantly moving water for sufficient aerated until they developed into fry. They were then transferred to larger tanks and fed zooplankton until they became large enough to digest pelleted feed.

Figures 15, 16, and 17: Vietnamese students capturing the some of the brood stock for culture.

Figure 18: Female carp being sexed. Figure 19: Male carp being sexed.


Figure 20: Students were required to count fish fry, 6000 to a bucket and they told me all of them had to be counted in the one large bucket. I am still not sure if I believe that since there were easily over 100 thousand.

Figure 21: fertilized eggs kept in constantly running water for sufficient aeration.

Figure 22: Fingerling snakehead that were being raised in the hatchery at Can Tho University.

Another aspect of aquaculture I learned about was filtration. In order to carry out such a significant operation on the campus it was essential to have high capacity filters. I had previously built my own filters in the past raising koi on my own but never had the chance to see one of this scale. The water first entered a chamber that moved slowly so as to allow suspended solids to fall out. The water was then pushed into a number of other chambers, each with mediums (usually stone) that were smaller than last. This not only filters the water of solids that may have not dropped out in the settlement chamber but also provides a substrate for beneficial bacteria, which reduces toxic nitrogen levels in the water from fish waste.

Figure 23: This is one of the many filters on the facility.

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Output 4: Impact Assessment on the Use of Low value and small sized fish versus formulated pellet feed for snakehead

Prepared by Le Xuan Sinh, Huynh Van Hien and Justin Grimm-Greenblatt

INTRODUCTION

Increasing demands for fish has resulted in a rapidly growing aquaculture industry in the Mekong Delta region of Cambodia and Vietnam. This increase in aquaculture development has resulted in a complementary increase in the demand for feed, much of which is low value/small sized fish and fish meal, popularly referred to as the "fish meal trap". This has resulted in a growing conflict between the use of low value/small sized fish for aquaculture feed and human consumption. Such an issue has the potential to threaten food security because many people in the Mekong Delta rely on low value/small sized fish for consumption. Furthermore the price of low value/small sized fish has tripled since 2001 and it is predicted to continue to rise as aquaculture expands making it more difficult to afford (FAO-APFIC, 2005).

One fishery that relies heavily on low value/small sized fish and fishmeal for food is the aquaculture of snakehead. Because of the high intensity need for low value/small sized fish, the Cambodian government placed a ban on snakehead aquaculture in 2004. This negatively impacted tens of thousands of snakehead farmers and has led to more illegal fishing activity in the region. However, the snakehead aquaculture fishery in Vietnam has grown substantially and has the potential to increase the conflict between the use of low value/small sized fish used for consumption and feed.

This conflict resulted in a project run by AquaFish Collaborative Research Support Project (CRSP) called, Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production, and Markets. The objectives of the project are as follows:

1. To domesticate wild snakehead to address the snakehead banning issue in Cambodia in order to lift the ban on snakehead culture in Cambodia
2. To study environment impacts, fish disease and biosecurity of snakehead farming in Vietnam
3. To provide recommendations for policy and best practices development of snakehead farming.

This project focuses on both (1) the aquaculture of carnivorous fish and the management of low value/trash fish by addressing the uses and bio-ecological characteristics of low value/trash fish and (2) exploring alternative feeds and feed technology for freshwater aquaculture. By understanding the social, economic, and environmental/natural resource needs and implications of freshwater aquaculture, this project hopes to create sustainable freshwater aquaculture development in the Lower MKD of Cambodia and Vietnam. This project also takes into account capture and culture fisheries and how they play a significant role in food security, poverty alleviation, and economies within Cambodia and Vietnam. It further addresses the combined management of capture and culture fisheries, and the competition and conflict that has increased between the uses of low value/trash fish for feed and human consumption.

Already, of this project has developed weaning methods so small, hatchery-reared snakehead can quickly adapt to pelleted diets. It was determined that snakehead survive as well on pelleted diets that have as much as 50% of the fish meal replaced with soybean meal. Issues relating to the processing of low value/small sized fish and value added products were determined. Policies and strategies were then recommended for market and trade, which help to maintain high quality, safe, and nutritious low value fish products for local and international trade. These policy recommendations can be found in the Sinh et al (2011) investigation. In order to evaluate the industry Sinh et al. (2011) and to analyze and identify barriers of entry and interactions between actors in each step of production a value chain analysis was used. This is defined as "the full range of activities which are required to bring a product or service from conception, through the intermediary phases of production, delivery to final consumers, and final disposal after use" (Kaplinsky and Morris, 2001).

The project consisted of two phases. Phase I consisted of developing and testing an alternative feed that replaced up to 50% of the fish meal with soy for snakehead culture while Phase II consisted of disseminate information about the alternative feed to farmers and others in the industry that would benefit from this technology. It is to now essential to measure the impact of Phase I (2007 – 2009) and Phase II (2009 – 2011) AquaFish CRSP. This investigation is an impact assessment of the development economics, and extension of pelleted snakehead feed in Vietnam.

MEKONG BASIN AND AQUACULTURE

In the Mekong Delta, which includes Vietnam and Cambodia, aquaculture has the potential to provide lower socioeconomic groups with more food, better nutrition, and increased income. It also stimulates economic growth and offers greater diversification of income (WF, 2008).

For several decades now, aquaculture in the Mekong Delta region of Vietnam has played an important role through its improvements in the provisions of animal protein, creation of jobs, and generation of income for the community. It has also contributed to the domestic consumption and exports of aquatic products of Vietnam. Fish comprise of approximately 70% of the animal protein intake by Vietnamese people in the Mekong Delta. Vietnam ranks third in the world for fish production (Ministry of Fisheries, 2005). Furthermore, Vietnam contributes between 55% and 60% of the total aquatic production of the Mekong Delta (Sinh, 2005). Of that, it produces 60% of the total aquatic production for export by Vietnam (Sinh, 2005). A portion of the fish produced in Vietnam is from aquaculture, which has grown significantly. The annual growth of aquaculture in Vietnam was 10-13% during the last decade.

Cambodia, also located in the Mekong Delta relies on aquaculture which has been growing at a faster rate than Vietnam. Aquaculture increased rapidly over the last two decades, with an average growth rate of 16.3 percent and in 2004 it represented 8.3 percent of total inland fisheries production (So et al. 2005). Rab et al. (2006) stated that it represents approximately 10% of the total inland fisheries for Cambodia and is playing a role towards augmenting fish production in Cambodia (Rab et al., 2006). There is clearly a large demand for fish in Cambodia because fish constitute for approximately 75% of the animal protein intake for the Cambodian households and most of it comes mainly from freshwater fisheries in both fresh and processed form (Hap, 1999).

One important group of species produced in the Mekong Delta is the snakehead; more specifically, the two species currently being cultured in the Mekong Delta are Channa striata, the snakehead murrel, and Channa micropeltes, the giant snakehead. Snakehead production in Vietnam has grown rapidly. In An Giang, Dong Thap, Long An, Can Tho, and Kien Giang Provinces of Vietnam, a total of 5,300 tonnes of snakehead were produced (Long, 2004). By 2008, snakehead production grew to about 30,000 tonnes and in 2010 it reached 40,000 tonnes according to the summary of annual reports of the Delta provinces (Le Xuan Sinh and Pomeroy, 2009; Le Xuan Sinh and Pomeroy, 2011).

The growth of snakehead farming has been quite the opposite in Cambodia due to the Cambodian government placing a country wide ban on the culturing of snakehead, starting in May of 2005. This decision was made because the government believed there were potential negative impacts on both wild populations of snakehead from wasteful seed collection and on lower socioeconomic groups of consumers who suffered from decreased availability of low value/small sized (So Nam and Hang, 2007). So Nam et al. (2009a) revealed that the ban imposed instead had negative impacts such as on the livelihoods of tens of thousands of snakehead farmers who depended on culturing snakehead. Furthermore, it increased pressure on wild snakehead stocks through illegal and destructive fishing gear such as electro shockers (So Nam et al. 2009a).

DISEASE

One issue involved with the production of snakehead in the Mekong Delta is the limitation of appropriate technologies to prevent high fish mortality caused by diseases while culturing. Disease outbreaks among snakehead are caused by 23 genera of parasites, 4 genera of fungi, and 81 strains of bacteria belonging to 5 genera (Pham Minh Duc et al., 2011). Farmers have utilized both modern and traditional medicine to cure disease-infected fish but this has had little success.

LOW VALUE /SMALL SIZED FISH

Another issue with the culture of snakehead is that supplies of small-sized/low value fish are finite, and as indicated by a recent increase in price, i.e. demand is outstripping supply, due to mainly to the depletion of fish stocks resulting from overfishing, human population growth, and ecosystem degradation (So Nam et al., 2009; Le Xuan Sinh and Pomeroy, 2009). Low value small sized fish are typically caught as by-catch, however, some small scale fishers have moved towards directly targeting these species such as a fishing fleet in Cat Lo, Vietnam because of the demand increase for low value/small sized fish (FAO, 2005; FAO-APFIC , 2005).

The lower MKD region is heavily dependent on low value/trash fish for the uses like (1) local consumption (e.g. fresh, dried); (2) direct feed (e.g. livestock, high value species aquaculture); (3) fish meal production (e.g. poultry, aquaculture); and (4) value-added products (e.g. fish sauce). 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, etc (Un Sophea et al., 2010; So Nam et al., 2009b; So Nam et al., 2009c). Proponents of this suggest small-sized/low value fish be used for food for poor domestic consumers since this would be more appropriate than supplying fish meal plants for an export income, producing high value commodities in aquaculture (Le Xuan Sinh and Pomeroy, 2009). 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 number of people employed in both fishing and aquaculture has this beneficial effect, via income generation, rather than direct food supply.

While it is difficult to accurately estimate the amount of trash fish caught per year, it appears that the demand for low value/small sized fish will increase as aquaculture in the region increases. In 2008, aquaculture production in Vietnam ranked third in the world with 2,462 thousand tones valued 4,510 million USD (Lymer et al. 2010). The FCR of for snakehead culture is four. Therefore, 120,000 tonnes of low value/small sized fish in 2009 and 160,000 tonnes in 2010 were used for feeding snakehead. This represents 17% and 23% of total annual freshwater fish production in the Mekong Delta of Vietnam in 2009 and 2010, respectively.

FISHMEAL

Low value small sized fish are also bought by fishmeal plants in order to produce fishmeal for pelleted feed for livestock and aquaculture. FAO-APFIC (2005) estimates that 280,000 tonnes of fishmeal is used in fishmeal plants each year. As aquaculture increases in Vietnam, the demand for fishmeal will increase especially for those cultures fed pelleted diets which contain fishmeal. As a result, the fishmeal in pelleted diets will need to be replaced with plant proteins if they cannot compete with fish meal on the local market (FAO, 2005). Piscivorous (fish-eating) fish like cultured snakehead typically require high levels of protein in their diet, reflecting the high protein in their natural diet. The usual source of that protein in pellet diets is fish meal.

Phase I Forumlated Feed Study

To meet the goal of creating pelleted diets, which contain plant proteins, qualitative and quantitative assessments of the regular freshwater low value/small sized fish diet for snakehead food were conducted. Then, a series of formulated feed experiments were conducted in the wet laboratory and in hapas located at the College of Aquaculture and Fisheries (CAF) of Cantho University (CTU) to develop formulated feed for snakehead culture. The experiments conducted were: (i) Weaning methods with formulated feeds for snakehead (Channa striata) larvae; (ii) Replacement of fishmeal with soybean meal (SM) with or without phytase and taurine in diets for Channa striata, and Channa micropeltes; (iii) Utilization of rice bran in snakehead Channa striata feed; (iv) Replacement of fishmeal with soybean meal with additions of soluble fish attractant or alpha-galactosidase in diets for Channa striata; (v) Replacement of freshwater trash fish by formulated feed in snakehead (Channa striata) and (Channa micropeltes) fingerling diets; (vi) Taste analysis of snakehead fed by different feeds.
These experiments concluded:

Thirty-three species of freshwater fish were identified as being used as “trash fish” or low-value fish for snakehead culture and the most abundant and common species is Cirrhinus lobatus. Chemical composition of some common species fluctuated from 14.3 to 16.5, 1.97-8.39, 2.48-4.67 in crude protein, crude lipid and crude ash, respectively. Most of those fishes were commercial species and some of them were target species for aquaculture in Vietnam, such as Anabas testudineus and Trichogaster trichopterus. Therefore, those fish stocks should be assessed and the inland fishery should be managed properly, especially in flood season.

These experiments also conclude valuable information involving the ability to culture snakehead on pelleted feed. Weaning onto formulated feed for snakehead larvae can begin by 17 days after hatch with replacement ratio of 10%.day^{-1} and up to 40% of fish meal in Channa striata and Channa micropeltes fingerling diets can be replaced by soybean meal with phytase supplements with no significant loss of growth performance, feed utilization, or survival of the two species. Rice-bran as well could be utilized by snakehead fingerlings with levels from 10% to 30% without any differences in growth performance and carcass composition. Hence, rice bran could be used in home-made formulated feed for snakehead fingerlings up to 30% to reduce feed cost.

Soybean meal can replace up to 60% of fish meal in the diet with the addition of phytase and alpha-galactosidase or fish solution feeding attractant. However, considering economic efficiency, protein soybean meal only can replace up to 50% of protein fish meal in the diet with the addition of phytase and alpha-galactosidase or fish solution feeding attractant. Moreover, 100% of the fresh water low value/small sized fish can be replaced with formulated feed in the diets of the two species of snakehead. If both growth performance and feed efficiency ratio were of interest, the replacement should stop at 50%. Thus, depending on a farmer’s situation, they should choose their own optimal solution for replacing fresh water trash fish by formulated feed in snakehead culture.

Taste of snakehead raised on a formulated feed was also of concern. C. micropeltes and C. striata fillet quality in a taste test was fairly liked and did not significantly differ between samples. In descriptive pair tests, there was no significant difference between samples. Thus, formulated feed (fish meal or plant protein) did not significantly affect the quality of fish fillet in both C. micropeltes and C. striata compared to a diet of trash fish.

Phase II Technology Transfer

Once the new pelleted feed for snakehead had been developed, it was made available to feed mills in the lower Mekong Delta region of Vietnam. By conducting inception workshops, dissemination workshops, impact assessment seminars, information/communication monitoring, evaluation workshops, and the creation of posters, the public was made aware of the new formulated pellet feed and the issues that surround the uses of low value/small sized fish. Furthermore the dissemination of information facilitated the technology transfer of the new feed technology to training extension workers from seven provinces who then trained farmers.

Methodology of Impact Assessment of Formulated Feed vs. Trash Fish

Agricultural research generates many types of outputs. These include technologies embodied in a physical object (e.g., improved feed), management tools and practices, information, and improved human resources. Impact assessment is a process of measuring whether or not research has produced its intended effect—that of meeting development objectives, such as increases in production and income and improvements in the sustainability of production systems. It is important to demonstrate that the changes observed are due to a specific intervention and cannot be accounted for in any other way. The effects can be measured at the household, target population, national, and regional levels. Impact assessment to be undertaken in this investigation will be of two types: ex-post and concurrent. The ex-post assessment refers to the evaluation made upon the completion of a project to determine achievements and to estimate the impact of research. Returns to investment in research and development are typically assessed using the ex-post concept. These studies also help to understand the process of disseminating technology and the constraints to its adoption. Concurrent assessment or evaluation is done to identify the impediments for larger adoption of the research outputs. The purpose of a concurrent evaluation is to correct the gaps and provide feedback for refining and tuning the technology as per the stakeholders' requirements. Often it is known as constraint analysis. Four components determine the adoption of a technology: technology traits (e.g. duration, quality, etc.), policy environment (e.g. price support, procurement, etc.), institutional arrangements (e.g. seed supply sector, credit availability, etc.), and infrastructure (e.g. markets, roads, power, clean water, processing facilities, etc.). Determining constraints for larger adoption forms a part of the impact assessment.

Eighty three farms that culture snakehead in An Giang and Dong Thap provinces of Vietnam participated in a survey, which obtained information on revenue, fixed costs, and variable costs. This data was entered into SPSS. Of the 83 farms that were surveyed, they were separated by whether they produced two crops per year or another amount of crops per year. Farms that produced two crops per year were the only ones used in this IA. This is because they were the most abundant among respondents and the ratio of capital costs to production may have not aligned with farms producing the same amount of crops per year. Of the farms that produced two crops per year, 37 fed snakehead culture with 100% low value/small sized fish and 44 utilized a pelleted feed. However, of these 44, some were fed a small percentage of low value trash fish and this was incorporated into the variable costs (max 16.10% of total feed on one farm). Farms that utilized 100% low value/small sized fish or pelleted feed were further broken into groups by their crop production. Farms producing 30,000 tonnes/crop of snakehead were chosen as the cut off because this was the median production amount. There were 15 farms producing 30,000 tonnes or less per crop of snakehead and 25 farms producing greater than 30,000 tonnes of snakehead per crop utilizing 100% low value/small sized fish for feed. There were 28 farms producing 30,000 tonnes or less of snakehead per crop and 16 producing greater than 30,000 tonnes of snakehead per crop utilizing pelleted feed. However, one farm produced 400 tonnes of snakehead utilizing pelleted feed and greatly influenced the average. It was therefore treated as an outlier and was not used. This would explain why n=15 for production greater than 30,000 tonnes of snakehead per crop for the pelleted feed group.

Utilizing SPSS, average revenue, average variable cost, and average total cost were calculated and imported into Microsoft Excel to create an enterprise budget. Revenue was found multiplying the average quantity of snakehead produced by the average selling price farmers were receiving.

Fixed costs included miscellaneous and construction of pond costs for farms utilizing 100% low value/small sized fish. It also includes the purchase of machine and construction of pond and culvert costs for both 100% low value/small sized fish and pelleted feed. These were all calculated by dividing the full cost of each item by their respective depreciation rate. This provided the yearly cost of each, which was summed to find the average total fixed cost. It was then divided by two to obtain the cost per crop.

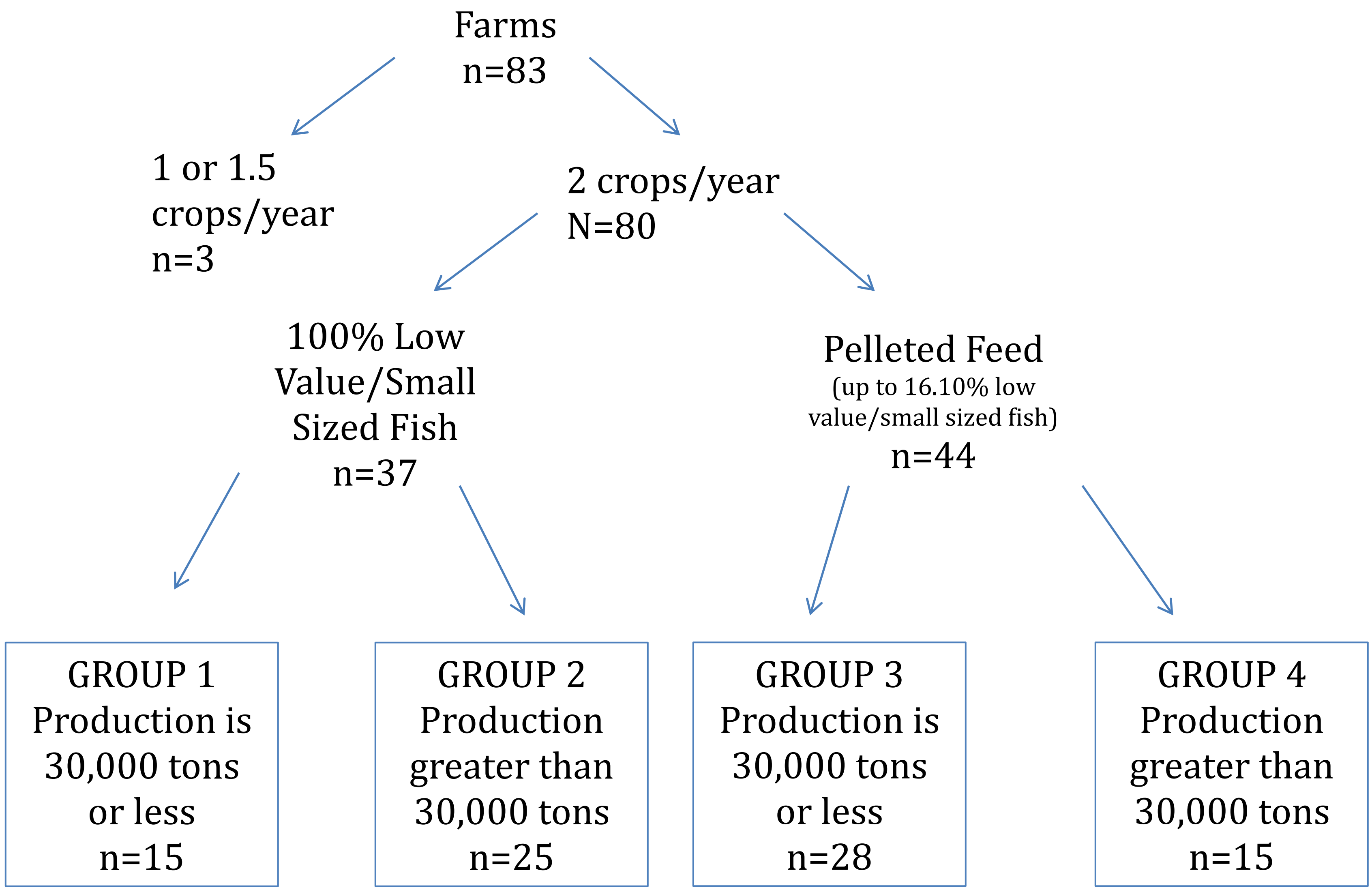

Figure 1: This figure shows how farms were broken into groups before the enterprise budget was calculated. The squared groups are the final groups that were used to calculate averages.

Variable costs included to market costs (transportation to market, boxes, other), tax, seed cost, pump water cost, treatment cost, low value small sized feed cost, pelleted feed cost (for farms utilizing pelleted feed), labor costs (permanent and temporary combined), and interest on loan cost. The data that did not have per unit costs made available by the data included to market costs, taxes, pump water cost, treatment cost, and spawning cost. Therefore, only the full average costs of these items was included. Seed quantity data was also not provided so it was back calculated by dividing the average cost of seed by the average price. Feed (both low value small sized fish and pelleted) were calculated by multiplying the average quantity by the average price. Average interest on loans was calculated by multiplying average interest rate by the loan. This provided the monthly interest rate, which was then multiplied by 6 to achieve the interest cost per crop. Each item was then multiplied by two to obtain the yearly cost.

Average total costs per crop and per year were then calculated by adding average fixed costs and average variable costs. This was then subtracted from the average total revenue per crop and per year to obtain the average net profit per crop and per year.

Next a price sensitivity tests was conducted by altering the price of feed and observing net profit changed within groups 1-4 in figure 1 on a per crop and a per year basis. This sensitivity test was repeated for groups 2 and 4 using equivalent variable costs instead of net profit. For group 3, small farms utilizing pelleted feed, some low value/small sized fish were also part of the cost. However, these were kept constant as pelleted feed prices changed. For group 4, large farms that utilized pelleted feed, some low value/small sized fish were also part of the cost. In this case the price of the low value/small sized fish were adjusted to match the price that group 2, large farms that utilized 100% low value/small sized fish paid.

RESULTS: SMALL FARMS

Table 1. This table shows the revenue, fixed costs, variable costs, and net profit of small farms utilizing low value/small sized fish for feed.

Revenue and Costs of Small Farms Using Pelleted Feed						
Gross Reciepts						
Gross Reciepts	**Quantity per crop**	**Quantity per year**	**Units**	**Price per unit (000'd)**	**Gross Rev. Per Crop (000'd)**	**Gross Rev. Per Year (000'd)**
Total Gross Reciepts	12,453.57	24,907.14	kg	41.92	**522,027.03**	**1,044,054.06**
Fixed Costs						
Fixed Costs	**Total Costs**			**Dep. Rate per yr**	**Cost Per Crop**	**Cost Per Year**
Miscellaneous other cost ('000d)	2,333.33			3.00	388.89	777.78
Construction pond cost ('000d)	29,750.00			3.00	4,958.33	9,916.67
Machine ('000d)	10,562.50			3.92	1,346.20	2,692.40
Construction of damn and culvert ('000d)	41,808.82			9.56	2,186.08	4,372.16
Total Fixed Cost (000'd)					**8,879.51**	**17,759.01**
Variable Costs						
Variable Costs	**Quantity**		**Units**	**Price per unit**	**Cost Per Crop**	**Cost Per Year**
Trans to market (000'd)					4,000.00	8,000.00
Boxes (000'd)					4,416.67	8,833.33
Other (000'd)					3,078.95	6,157.89
Tax (000'd)					6,666.67	13,333.33
Seed cost (000'd)	48,107.14		Ind.	0.26	12,370.41	24,740.82
Pump water (000'd)					6,326.79	12,653.57
Treatment (000'd)					15,160.71	30,321.43
Low value/small sized fish	5,142.99		kg	8.43	43,379.99	86,759.99
Pelleted feed ('000d)	28,500.03		kg	22.02	627,509.64	1,255,019.27
Labor (perm. and temp.) (000'd)					4,388.46	8,776.92
Interest on Loan (000'd)	**Interest rate**	**Loan amount**	**Unit**	**Price Per Unit**		
	1.99	157,720.00	Month	3,140.14	37,511.38	75,022.77
Total Variable Cost (000'd)					**764,809.66**	**1,529,619.33**
Total Cost (000'd)					**773,689.17**	**1,547,378.34**
Net Profit (000'd)					**(251,662.14)**	**(503,324.28)**

Table 2. This table shows the revenue, fixed costs, variable costs, and net profit of small farms utilizing low value/small sized fish for feed.

Revenue and Costs of Small Farms Using 100% Low Value/Small Sized Fish for Feed						
Gross Reciepts						
Gross Reciepts	Quantity per crop	Quantity per year	Units	Price per unit (000'd)	Gross Rev. Per Crop (000'd)	Gross Rev. Per Year (000'd)
Total Gross Reciepts	18,300.00	36,600.00	kg	40.71	**745,071.43**	**1,490,142.86**
Fixed Costs						
Fixed Costs	Total Costs			Dep. Rate per yr	Cost Per Crop	Cost Per Year
Miscillaneous other cost ('000d)	4,125.00			7.50	275.00	550.00
Construction pond cost ('000d)	20,898.00			7.67	1,362.91	2,725.83
Machine ('000d)	15,039.92			6.57	1,144.34	2,288.68
Construction of damn and culvert ('000d)	44,000.00			7.67	2,869.57	5,739.13
Total Fixed Cost (000'd)					**5,651.82**	**11,303.64**
Variable Costs						
Variable Costs	Quantity		Units	Price per unit	Cost Per Crop	Cost Per Year
Trans to market (000'd)					444.44	888.89
Boxes (000'd)					1,687.50	3,375.00
Other (000'd)					1,200.00	2,400.00
Tax (000'd)					2,200.00	4,400.00
Seed cost (000'd)	49,142.86		Ind.	0.31	15,199.18	30,398.37
Pump water (000'd)					66,312.31	132,624.62
Treatment (000'd)					29,807.69	59,615.38
Low value/small sized fish	78,540.37		kg	7.92	622,214.29	1,244,428.57
Pelleted feed ('000d)	0		kg	0	0	0
Labor (perm. and temp.) (000'd)					6,491.67	12,983.33
Interest on Loan (000'd)	Interest rate	Loan Amount	Unit	Price Per Unit		
	2.49	312,692.31	('000d)	7,778.22	46,669.33	93,338.65
Total Variable Cost (000'd)					**792,226.41**	**1,584,452.81**
Total Cost (000'd)					**797,878.23**	**1,595,756.46**
Net Profit (000'd)					**(52,806.80)**	**(105,613.60)**

Fixed Cost

Small farms utilizing 100% low value/small sized fish incurred total fixed cost of 5,651.82 (000'd) per crop and 11,303.64 (000'd) per year. These fixed costs consisted of a miscellaneous cost, construction of pond cost, machine cost, and construction of damn and culvert cost, which were 275.00 (000'd) per crop and 550.00 (000'd) per year, 1,362.91 (000'd) per crop and 2,7525.83 (000'd) per crop, 1,144.34 (000'd) per crop 2,288.68 (000'd) per year, and 2,868.57 (000'd) per crop and 5,739.13 (000'd) per year respectively.

Small farms utilizing pelleted feed incurred a higher total fixed cost than the small farms utilizing 100% low value/small sized fish for feed. The small farms utilizing pelleted feed had an total fixed cost of 8,879.51 (000'd) per crop and 17,759.01 (000'd) per year. The small farms utilizing pelleted feed also incurred the same fixed costs, which were miscellaneous costs, construction of pond cost, machine cost, and construction of damn and culvert cost. However, they differ in value from the other farms with costs in the respective order as listed before, 388.89 (000'd) per crop 777.78 (000'd) per year, 4,958.33 (000'd) per crop and 9,916.67 (000'd) per year, 1,346.20 (000'd) per crop and 2,692.40 (000'd) per year, and 2,186.08 (000'd) per crop and 4,372.16 (000'd).
Variable Cost

Small farms utilizing 100% low value/small sized fish for feed incurred a total variable cost of 792,226.41 (000'd) per crop and 1,584,452.81 (000'd) per year. This consisted of to market costs incorporating transportation to market, boxes, and other costs, which were 444.44 (000'd) per crop and 888.89 (000'd) per year, 1,687.50 (000'd) per crop and 3,375.00 (000'd) per year, and 1,200.00 (000'd) per crop and 2,400.00 (000'd) per year respectively. Total variable cost also consists of tax, seed cost, pump water cost, treatment cost, low value small sized feed cost, labor costs (permanent and temporary combined), and interest on loan cost, which were 2,200.00 (000'd) per crop and 4,400.00 (000'd) per year, 15,199.18 (000'd) per crop and 30, 398.17 (000'd) per year, 66,312.31 (000'd) per crop and 132,624.62 (000'd) per year,622,214.29 (000’d) per crop and 1,244,428.57 (000’d) per year, 6,491,67 (000’d) per crop and 12,983.33 (000’d) per year, and 46, 699,33 (000’d) per crop and 93,338.65 (000’d) per year respectively.

Small farms utilizing pelleted feed incurred a lower total variable cost of 764,809.66 (000’d) per crop and 1,529,619.33 (000’d) per year. This also consisted of to market costs incorporating transportation to market, boxes, and other costs. In respective order they were 4,000.00 (000’d) per crop and 8,000.00 (000’d) per year, 4,416.67 (000’d) per crop and 8,833.33 (000’d) per year, and 3,078.95 (000’d) per crop and 6,157.98 (000’d) per year. Total variable cost also consisted of tax, seed cost, pump water cost, treatment cost, low value/small sized feed cost, pelleted feed, labor costs (permanent and temporary combined), and interest on loan cost, which were 6,666.67 (000’d) per crop and 13,333.33 (000’d) per year, 12,370.41 (000’d) per crop and 24, 740.82 (000’d) per year, 6,326.79 (000’d) per crop and 12,653.57 (000’d) per year,15,160.71 (000’d) per crop and 30,321.43 (000’d) per year, 43,379.99 (000’d) per crop and 86,759.99 (000’d) per year, 627, 509,64 (000’d) per crop and 1,255,019.27 (000’d) per year, and 4,388.46 (000’d) per crop and 8,776.92 (000’d) per year respectively.

Revenue, Total Cost, and Net Profit

The revenue achieved by small farms utilizing 100% low value/small sized fish for feed was 745,071.43 (000’d) per crop and 1,490,142.86 (000’d) per year, while the total cost was 797,878.25 (000’d) per crop and 1,595,756.46 (000’d) per year. This caused a net loss of 52,806.80 (000’d) per crop and 105,613.60 (000’d) per year.

Like the small farms utilizing 100% low value/small sized fish for feed, the small farms utilizing pelleted feed were also producing at a net loss. They lost 255,662.14 (000’d) per crop and 503,324.28 (000’d) per year. The revenue for these farms was 522,027.03 (000’d) per crop and 1,044,054.06 (000’d) per year, while the total cost was 773,689.17 (000’d) per crop and 1,547,378.84 (000’d) per year.

RESULTS: LARGE FARMS

Table 3. This table shows the revenue, fixed costs, variable costs, and net profit of small farms utilizing low value/small sized fish for feed.

Revenue and Costs of Large Farms Using 100% Low Value/Small Sized Fish for Feed						
Gross Reciepts						
Gross Reciepts	Quantity per crop	Quantity per year	Units	Price per unit (000'd)	Gross Rev. Per Crop (000'd)	Gross Rev. Per Year (000'd)
Total Gross Reciepts	65,136.36	130,272.73	kg	43.82	**2,854,157.02**	**5,708,314.05**
Fixed Costs						
Fixed Costs	Total Costs			Dep. Rate per yr	Cost Per Crop	Cost Per Year
Miscellaneous other cost ('000d)	1,833.33			10.00	91.67	183.33
Construction pond cost ('000d)	48,250.00			9.40	2,566.49	5,132.98
Machine ('000d)	40,538.46			8.40	2,413.00	4,826.01
Construction of damn and culvert ('000d)	77,529.41			9.25	4,190.78	8,381.56
Total Fixed Cost (000'd)					**9,261.94**	**18,523.88**
Variable Costs						
Variable Costs	Quantity		Units	Price per unit	Cost Per Crop	Cost Per Year
Trans to market (000'd)					600.00	1,200.00
Boxes (000'd)					10,238.89	20,477.78
Other (000'd)					1,304.55	2,609.09
Tax (000'd)					111.11	222.22
Seed cost (000'd)	180,681.82		Ind.	0.35	63,443.96	126,887.91
Pump water (000'd)					35,500.00	71,000.00
Treatment (000'd)					44,095.24	88,190.48
Low value/small sized fish	231,627.91		kg	8.06	1,866,920.93	3,733,841.86
Pelleted feed ('000d)	0		kg	0	0	0
Labor (perm. and temp.) (000'd)					14,615.26	29,230.53
Interest on Loan (000'd)	Interest rate	Loan amount	Unit	Price Per Unit		
	1.76	742,307.69	('000d)	13,072.43	78,434.57	156,869.15
Total Variable Cost (000'd)					**2,115,264.51**	**4,230,529.02**
Total Cost (000'd)					**2,124,526.45**	**4,249,052.89**
Net Profit (000'd)					**729,630.58**	**1,459,261.16**

Table 4. This table shows the revenue, fixed costs, variable costs, and net profit of large farms utilizing low value/small sized fish for feed.

Revenue and Costs of Large Farms Using Pelleted Feed						
Gross Reciepts						
Gross Reciepts	Quantity per crop	Quantity per year	Units	Price per unit (000'd)	Gross Rev. Per Crop (000'd)	Gross Rev. Per Year (000'd)
Total Gross Reciepts	61,071.43	122,142.86	kg	40.71	2,486,479.59	4,972,959.18
Fixed Costs						
Fixed Costs	Total Costs			Dep. Rate per yr	Cost Per Crop	Cost Per Year
Miscillaneous other cost ('000d)	0			0	0	0
Construction pond cost ('000d)	0			0	0	0
Machine ('000d)	4,888.89			1.22	2000.00	4000.00
Construction of damn and culvert ('000d)	70,590.91			10.91	3235.42	6470.83
Total Fixed Cost (000'd)					5,235.42	10,470.83
Variable Costs						
Variable Costs	Quantity		Units	Price per unit	Cost Per Crop	Cost Per Year
Trans to market (000'd)					0	0
Boxes (000'd)					7,000.00	14,000.00
Other (000'd)					4,480.00	8,960.00
Tax (000'd)					8,000.00	16,000.00
Seed cost (000'd)	219,285.71		Ind.	0.28	60,773.47	121,546.94
Pump water (000'd)					25,642.86	51,285.71
Treatment (000'd)					43,571.43	87,142.86
Low value/small sized fish	6,966.68		kg	8.22	57,266.10	114,532.19
Pelleted feed ('000d)	46,375.84		kg	22.21	1,030,206.22	2,060,412.45
Labor (perm. and temp.) (000'd)					18,900.00	37,800.00
Interest on Loan (000'd)	Interest rate	Loan amount	Unit	Price Per Unit		
	0.84	737,500.03	('000d)	6,203.79	37,222.73	74,445.47
Total Variable Cost (000'd)					1,293,062.81	2,586,125.62
Total Cost (000'd)					1,298,298.23	2,596,596.45
Net Profit (000'd)					1,188,181.37	2,376,362.73

Fixed Cost

Large farms utilizing 100% low value/small sized fish for feed incurred a total fixed cost of 9,261.94 (000’d) per crop and 18,523.88 (000’d) per year. This consisted of a miscellaneous cost, construction of pond cost, machine cost, and construction of damn and culvert cost, which were 91.67 (000’d) per crop and 183.33 (000’d) per year, 2,566.49 (000’d) per crop and 5,132.98 (000’d) per crop, 2,143.00 (000’d) per crop 4,826.01 (000’d) per year, and 4,190.78 (000’d) per crop and 8,381.56 (000’d) per year respectively.

Large farms utilizing pelleted feed incurred a lower average total fixed cost of 5,235.42 (000’d) per crop and 10,470.83 (000’d) per year. Unlike large farms utilizing 100% low value/small sized fish for feed, these farms only had fixed costs consisting of a machine cost and a construction of damn and culvert cost. In the respective order they were 2,000 (000’d) per crop 4,000 (000’d) per year, 3,235.42 (000’d) per crop and 6,470.83(000’d).

Variable Cost

Large farms utilizing 100% low value/small sized fish for feed incurred a total variable cost of 2,115,264.51 (000’d) per crop and 4,230,529.02 (000’d) per year. This consisted of to market costs such as transportation to market, boxes, and other costs, which were 600.00 (000’d) per crop and 1,200.00 (000’d) per year, 10,238.89 (000’d) per crop and 20,477.78 (000’d) per year, and 1,304.55 (000’d) per crop and 2,609.09 (000’d) per year respectively. Total variable cost also consisted of tax, seed cost, pump water cost, treatment cost, low value small sized feed cost, labor costs (permanent and temporary combined), and interest on loan cost, which were 111.11 (000’d) per crop and 222.22 (000’d) per year, 66,443.96 (000’d) per crop and 126, 887.91 (000’d) per year, 35,500.00 (000’d) per crop and 71,000.00 (000’d) per year, 44,095.24 (000’d) per crop and 88,190.48 (000’d) per year, 6,344.44 (000’d) per crop and 12,68.89 (000’d) per year, and 78, 434.57 (000’d) per crop and 156,869.15 (000’d) per year respectively.

The large farms utilizing pelleted feed incurred a lower total variable cost of 1,291,948.14 (000’d) per crop and 2,583,896.28 (000’d) per year. Unlike the large farms utilizing 100% low value/small sized fish for feed, these farms had to market costs that consisted of only box cost and other cost. They were 7,000 (000’d) per crop and 14,000.00 (000’d) per year and 4,480.00 (000’d) per crop and 8,960.00 (000’d) respectively. Total variable cost also consisted of tax, seed cost, pump water cost, treatment cost, low value/small sized feed cost, pelleted feed, labor costs (permanent and temporary combined), and interest on loan cost, which were 8,000.00 (000’d) per crop and 16,000.00 (000’d) per year, 60,773.47 (000’d) per crop and 121, 546.94 (000’d) per year, 25,642.86 (000’d) per crop and 51,285.71 (000’d) per year,43,571.43 (000’d) per crop and 87,142.86 (000’d) per year, 5,178,892.86 (000’d) per crop and 10,357,785.71 (000’d) per year, 56,151.43 (000’d) per crop and 112,302.86 (000’d) per year, and 1,030,206.22 (000’d) per crop and 2,060,412,.45 (000’d) per year, 18,900 (000’d) per crop and 37,800 (000’d) per year, and 37,222.73 (000’d) per crop and 74,445.47 (000’d) per year respectively.

Revenue, Total Cost, and Net Profit

The revenue achieved by large farms utilizing 100% low value/small sized fish for feed was 2,854,157.02 (000’d) per crop and 5,708,314.05 (000’d) per year, while the total cost was 2,124,526.45 (000’d) per crop and 4,249,052.89 (000’d) per year. This caused a net gain of 729,630.58 (000’d) per crop and 1,459,261.16 (000’d) per year.

Making a larger portion of profit than the large farms utilizing 100% low value/small sized fish for feed, the large farms utilizing pelleted feed made1,188,181.37 (000’d) per crop and 2,376,362.73 (000’d) per year . The revenue for these farms was 2,486479.59 (000’d) per crop and 4,972,959.18 (000’d) per year, while the total cost was 1,298,298.23 (000’d) per crop and 2,596,596.45 (000’d) per year.

DISCUSSION

Currently there is no time series data available for low value/small size fish prices. However, the Edwards et al. 2004 report for the Australian Centre for International Agricultural Research interviews several farmers and low value/small size fish fishermen from different provinces of the Lower Mekong. It was reported that the price of trash fish rose significantly and in some cases almost doubled from three years prior to the interviews.

This increase in price has already begun to negatively affect farmers, especially small farmers who rely heavily on low value/small size fish, which has resulted in net losses (Table 2). This is shown by the fact that small farms using 100% low value/small size fish for feed were losing -52,806.80 (000’d) per crop and -105,613.60 (000’d) per year. Small farmers utilizing pelleted feed are producing at an even greater loss (-251,662.14 (000’d) per crop and -503,324.28 (000’d) per year) because the pelleted feed is still too expensive. The revenue made by small farmers that utilize 100% low value/small sized fish for feed and ones utilizing pelleted feed are able to cover their fixed costs but not their total costs (table 1 and 2). This is discerning because this is not sustainable in the long run.

In order for these small farms to no longer produce at a net loss, the price of low value/small sized fish or pelleted feed must decrease in price. More specifically, the current price of low value small sized fish for farms utilizing 100% low value/small sized fish for feed must drop from 7.92 (000’d) per kg to approximately 7.25 (000’d) per kg. Since the prices of low value/small size fish has increased significantly over the last decade, this seems unlikely. Therefore, small farms must rely on a decrease in price in pelleted feed. In order for small farms utilizing pelleted feed to be cover their costs the price of pelleted feed would need to drop from its current price of 22.02 (000’d) per kg to approximately 13.18 (000’d) per kg (This is considering that the current price of low value small sized fish for farms utilizing pelleted feed remains at given that the price of low value/small sized fish price remains at 8.43 (000’d) per kg). Furthermore, small farms not exposed to the idea of using pelleted feed would also need to be educated about this option if the price decreased enough.

Large farms on the other hand are incurring a profit and more so for the farms utilizing the pelleted feed (table 3 and 4). It is therefore expected that large farms not using pelleted feed will switch to pelleted feed once they are made aware of its benefits. However, if the price of low small/size fish were to decrease from 8.06 (000'd) to approximately 6.01 (000'd) or less, farmers would begin to switch back to using low value/small sized fish (this is considering that the large farms utilizing pelleted feed pay an equivalent price of 6.01 (000'd) for the small percentage (16.5%) of low value/small sized fish they also use and the price of pelleted feed remains constant). Using equivalent variable costs to find the price at which farmers would begin to switch back to small sized/low value fish, it was found that the price of low value small/sized fish would need to decrease to approximately 4.40 ('000d) per kg or less (this is considering that the price of low value/small sized fish on farms utilizing pelleted feeds is adjusted from 8.22 (000'd) per kg to 8.06 ('000d) per kg in order to match the 100% low value/small sized fish and ones utilizing price paid by farms utilizing 100% low value/small sized fish for feed).

In the case where large farms utilizing pelleted feed begin to switch to low value/small sized fish, the price of pelleted feed would need to increase from 22.21 ('000d) per kg to approximately 32.13 ('000d) per kg or greater (this is considering that the price of low value/small sized fish on farms utilizing pelleted feeds is adjusted from 8.22 (000'd) per kg to 8.06 ('000d) per kg in order to match the 100% low value/small sized fish and ones utilizing price paid by farms utilizing 100% low value/small sized fish for feed) . Using equivalent variable costs to find the price at which farmers would begin to switch to using small sized/low value fish, it was found that the price of pelleted feed would need to increase to approximately 35.91 ('000d) or greater (this is considering that the price of low value/small sized fish on farms utilizing pelleted feeds is adjusted from 8.22 (000'd) per kg to 8.06 ('000d) per kg in order to match the 100% low value/small sized fish and ones utilizing price paid by farms utilizing 100% low value/small sized fish for feed).

CONCLUSION

The future of small snakehead farms is questionable, while large snakehead farms remain profitable. The cost of small sized/fish has increased significantly enough over the last decade to only allow small farms to cover their fixed costs and this is not sustainable in the long term. For the small farms utilizing pelleted feed, the price of pelleted feed is still too high and they also can only cover fixed costs. The future of these small snakehead farms relies on either a decrease in price of low value/small sized fish or decrease in the price of pelleted feed. However, it is unlikely that the price of low value/small sized fish would decrease since it has increased significantly over the last decade. Therefore, it is essential that the price pelleted feed decrease.

In order for the price of pelleted feed to decrease significantly enough to allow small farms to be sustainable, the supply to market must increase. This is likely since large farms relying on pelleted feed are more profitable than large farms relying on 100% low value/small sized fish for feed. Therefore, it is expected that as information about pelleted feed is more widely distributed, more large farms will demand it increasing the market supply and decreasing its prices. However, the rate at which these prices will decrease is unknown and therefore, it is unclear on whether the price will decrease significantly enough and at an appropriate rate to make small farms sustainable in a timely enough fashion.

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