TOPIC AREA

POLICY DEVELOPMENT

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GUIDANCE AND POLICY RECOMMENDATIONS FOR SUSTAINABLE SNAKEHEAD AQUACULTURE AND AQUATIC RESOURCE MANAGEMENT IN CAMBODIA AND VIETNAM

Policy Development/Activity/16PDV01UC

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ABSTRACT

Investigation 2 was conducted with the goal to clarify and provide science-based guidance and policy recommendations related to stakeholders involved in snakehead industry for sustainable snakehead aquaculture in Cambodia and Vietnam. The research includes four activities: i) A desk-study on cost-profit in different snakehead farming models and scale based on previous study; ii) Audience analysis; iii) Reviewing project products and consulting experts to extract key message; and iv) communication and dissemination strategy. The study was based on previous research undertaken under the AquaFish CRSP and AquaFish Innovation Lab in Cambodia and Vietnam that focused on value chain analyses to provide more in-depth understanding of cost and profitability of snakehead culture. The results of activity 1 shows that cage and pond culture system were both commonly used in Cambodia. The results of the study in 2006 indicated that snakehead cage culture had higher profitability compared to pond culture system, USD 570 per cage per cycle and USD 29 per pond per cycle, respectively. There was similar results from the study in 2011, the net profit for small scale cage culture was negative, while medium scale had a gain in profit of USD 4,353. For pond culture, the net profit for small, medium, and large scale were all negative. Both cage and pond culture systems in 2016 show loss in net profit. Cage culture farmers lost approximately USD 336 per cage per cycle and for farmers who applied pond system, they lost about USD 11,491. The major contribution that led to increases in operational production cost for both cage and pond culture system in Cambodia and Vietnam derives from feed cost. As clearly seen in study in Cambodia, the highest costs for snakehead cage and pond culture operation came from fish feed which contributes about 81% for cage and 75% for pond, respectively. The cost benefit analysis of fish cage culture indicates that the gross return per cage unit was 24,800,000 Riel (USD[3] 6,200) per cycle of fish raising, whereas the net profits was 3,310,000 Riel (USD 828). This figure excludes salary or wage of labor. However, on including the cost of wage labor, the net profit stands out at 1,510,000 Riel (USD 378),

[3] Assuming the exchange rate is : 1 USD = 4,100 Riel

which is about 54% of the total net profits. Of the total input costs, the highest costs for fish culture operation was fish feed, which contributes to about 74% of the total costs. This implies that the fish cage culture operation was profitable and is expected to continue in business. This suggests that the fishing household should have at least one cage culture in each household for improving their income and living condition.

In Vietnam pond culture and hapa were popular systems. Currently, almost all pond farms and nearly 90% of hapa model used pellet. Regarding scale production, pond culture with medium scale (1,000 – 2,000 m^2) brought highest profit (30 – 40 ton/farms and 11.31 USD/m^3/crop). In hapa system, farmers could be most profitable with 1.42 – 9.76 USD//m^3/crop (hapa in pond) and 1.29 – 10.9 USD/m^3/crop (hapa in river). Training-workshop organized in activity 2 revealed that diversity in snakehead culture models was still necessary for different farmers. Seed quality, disease management, and market function were key challenges. Support from authority in anticipation of market equilibrium production was requirement. Activity 3 also gave pragmatic recommendations, including Policy brief, guidelines, poster, leaflet and factsheet. Such materials were disseminated to propaganda and appropriate beneficiary in activity 4.

INTRODUCTION

Snakehead is a typical species of fresh water, which is raised in the Mekong Delta (MD) and cage culture in Cambodia. This species is considered as an easy species to grow with different models and scales (Sinh et al., 2009). Snakehead fish farming systems in the MD are now mainly earthen pond and hapa (in pond and in the river). Additionally, fish are also raised plastic tank and cage. The two main snakehead species currently cultured are *Channa striata* and *Channa micropeltes* (accounting for 20%) (Chung and Sinh, 2011). Snakehead is also chosen for small-scale production for the purpose of reducing poverty and replacing the ever-decreasing natural snakehead (Sinh et al., 2009). Snakehead culture are concentrated mainly in An Giang, Dong Thap, Can Tho, Hau Giang, Vinh Long and Tra Vinh provinces. Production increased rapidly from 5,300 tons in 2002 to 40,000 tons in 2010 (Long et al., 2004; Chung and Sinh, 2011). Snakehead is also chosen for small-scale production for the purpose of reducing poverty and replacing the ever-decreasing natural snakehead (Sinh et al., 2009). Within the freshwater aquaculture model in Cambodia, cage culture represents the highest percentage of about 70% of aquaculture production, while pond culture covers only 30%. The most important and highest profit fish species in cage culture system in Cambodia is Chhdaur (Giant Snakehead, Channa Micropeltes) (So et al., 2005). Giant snakehead is commonly raised in cages in and along the Mekong River, the Great Lake Tonle Sap and Tonle Sap River (Hap and Pomeroy 2010).

In April 2016, the Government of Cambodia lifted the decade-old ban on snakehead fish farming following a request from the Ministry of Agriculture to allow farmers to fish. Signed by Bun Uy, a secretary of state at the Council of Ministers, the statement said the decision to legalize snakehead fish farming again would be accompanied by forthcoming conditions and advice for farmers. In the statement, Mr. Uy said the conditions and advice, to be issued by the Agriculture Ministry, would help farmers sustainably manage and maintain their farms, and keep fish stocks healthy.

Previously, snakehead was usually fed with fresh feed, mainly marine small-size fish, freshwater small-size fish and yellow snail (Chung and Sinh, 2011). The use of small-size fish/low value fish as directly feed to snakehead fish farming has caused environmental problems, increased pathogens leading to mass death due to poor water quality (So Nam and Robert Pomeroy, 2011). In addition, the conflict in the use of small-size fish for aquaculture and food consumption is increasingly as less and less fishing yields of small-size fish that lead to increase in price of small-size fish (Navy and Pomeroy, 2009). These circumstances have driven many studies in pellets aimed to replace small-size fish in snakehead fish farming. The success of complete conversion to pellet feed has contributed to

the rapid development of aquaculture, productivity increase and poverty reduction (Sinh et al., 2009). However, the significant increase in snakehead production has led to sharp fluctuation in market price from 2013. In addition, climate change, rising temperature and salinity intrusion also affected considerably to snakehead fish farming, especially the increase in investment cost while market price was still low that leaded to losses in recent years (Tran Hoang Tuan et al., 2014). Therefore, the review of cost-benefit efficiency along with changes in farming techniques of different models and scales of snakehead farming is necessary to see the trend of development, find out the success stories and issues as well as proposing necessary policies for sustainable snakehead farming in the Mekong River.

Therefore, this investigation utilizes this broad research on snakehead aquaculture to support the development of sustainable snakehead aquaculture in Cambodia through research based on guidance to farmers on feeding, breeding, weaning and rearing/grow-out. The lifting of the snakehead ban in Cambodia in April 2016 will allow for enhanced trade and investment for Cambodian farmers as snakehead is in high demand both domestically and regionally and there will be investment in feed mills, grow-out operations, processing and other post-harvest activities.

OBJECTIVE

The objective of this activity is to provide science-based guidance and policy recommendations to government and farmers and households, including vulnerable subpopulations such as women and children, on sustainable snakehead aquaculture in Cambodia and Vietnam.

MATERIALS AND METHODS

To support sustainable snakehead aquaculture, there is a need to provide science-based information to government, households and vulnerable populations in order to be able to make informed and deliberate decisions on snakehead aquaculture. As an activity, the purpose is not to generate new information but to disseminate and communicate information generated by the studies in the project. Specifically, science-based guidance and policy recommendations. This investigation will provide the information through a suite of different communication methods and approaches for each audience.

Key activities will include:

Activity 1. To examine the cost and profitability for snakehead culture in different production systems in Cambodia and Vietnam. These activities were carried out on previous research undertaken under the AquaFish CRSP and Innovation Lab in Cambodia and Vietnam that focused on snakehead value chain analyses to provide a more in-depth understanding of cost and profitability of snakehead culture. The activities were focus on snakehead culture in cage and pond production systems at different scales of production (small, medium, large). An extensive review of past studies was carried out in relation to production cost and profitability of snakehead culture in Cambodia and Vietnam. The review and desk-based research were help to establish the nature of costs involved in each type of production system i.e., categories of capital and labor used in snakehead culture. Specific information to be obtained will include investment cost, operational/variable input costs (seed, feed, chamical and drug), fixed costs (insurance, permits, license, tax, interest rate on borrowed fund and repair/maintenance etc.), total cost, selling price, gross and net income.

Synthesis method in activity 1 as follow:

- ***Step 1*:** To gather all related AquaFish and general papers/articles, including 27 papers in Vietnamese version and 7 previous reports from the project.
- ***Step 2*:** To set up review framework, research team proceeded separation and reviewing papers. Summary cost and profit in snakehead culture during different periods was conducted and filled of framework after that.
- ***Step 3***: Preparing report based on reviewed information. This report will be presented for activity 2: Audience analysis.

Activity 2: Audience analysis. The identification of target audiences including scientists, researchers, resource managers, government officials, NGOs, farmers, women and their specific information requirements and methods of receiving information (workshops, trainings) and appropriate communication products (e.g. policy briefs, technical report, journal articles, web media) and the style of communication including scope, where and how to receive information, language, technical content. Focus Group Discussions (FGDs) will be conducted with each audience group to identify appropriate communication channels for information dissemination and their preferences of communication channels.

In Cambodia, three FGDs were conducted in Battambang (21 June 2017), Kompong Thom (22 June 2017) and National level at the Inland fisheries research and development institute, Phnom Penh (11 July 2017). In Vietnam also three FGDs were conducted in An Giang (19 April 2017), Tra Vinh (26 April 2017) and Can Tho (9 May 2017) under the name of "Workshop-training on snakehead culture development sustainability based on audience analysis". The total number of participants for Cambodia was 138 which was divided into three groups (Table 1): Group delegates from farmers (Small, Medium and large); Group delegates from private sector (Hatchery/Nursing, Feed and chemical company processor and trader) and Group delegates from government official (aquaculture and fisheries official, researcher and policy maker and Chan Tho university, Vietnam). In Vietnam there were 140 participants (Table 5). The Objective of the workshop was to propose solutions for sustainable snakehead culture. All Delegates were divided into three groups: Group 1: Delegates from feed processing companies; Group 2: Delegates from management offices, researchers, experts and NGOs; Group 3: Fish culture farmers, snakehead seed producers, traders and snakehead processing facilities. The workshop followed three steps:

- ***Step 1***: participants were introduced the information on cost-profit in snakehead culture which taking out from activity 1.
- ***Step 2:*** participants were divided into three groups to discuss about three groups of indicators as follow:

Technical indicators:

Interpretations	**What is the present in the locality?**	**What is difficulties? Or shortage?**	**What is a proposed solution? Who will do it? How to apply?**
1. Seed production (broodstocks, nursing, quality)			
2. Farming models (Pond, hapa,tank….) land use?			
3. Scale (small, medium, large)?			
4. Farming technique			
5. Feeds and drugs/chemicals			
6. Environment & diseases?			
7. Others ……			

Market indicators:

Interpretations	**What is the present in the locality?**	**What is difficulties? Or shortage?**	**What is a proposed solution? Who will do it? How to apply?**
1. Markets (domestic and export)?			
2. Raw materials for processing? Processing capacity? Processing products? Processing technique?			

3. Distribution channels?			
4. Market price?			
5. Others ……..			

Political indicators:

Interpretations	**What is the present in the locality?**	**What is difficulties? Or shortage?**	**What is a proposed solution? Who will do it? How to apply?**
1. Planning			
2. Investment from government and private sector?			
3. Extension?			
4. Labors?			
5. Production cooperation? (cooperatives)			
6. Investment attraction?			
7. Others ……..			

Proposing communication products and how to approach products

Necessary communication products	**Approached method**	**Places to approach products**
1.		
2.		

- ***Step 3:*** One person on behalf of each group presented their discuss result and recommendation.

Activity 3. Project products. The project documents from all of the activities of the CRSP and Innovation Lab projects were reviewed, and team members consulted to extract key messages to be presented in the different communication products.

Activity 4. Communication and dissemination strategy. A communication strategy was formulated and implemented by the host country partners. The communication strategy is a combination of approaches, techniques and messages to reach different audiences. Printed media such as policy briefs, guidelines, posters, leaflets and flyers will be developed for dissemination. At a minimum, the strategy will aim to effectively disseminate the results of the following to key audiences.

RESULTS

Activity 1: Cost-Profit Analysis

Cambodia was divided into two different system, include pond and cage in the river or lake. For each system, it was divided into three scale including small-scale, medium scale and large scale. In general, farmers were culturing the snakehead in cage and pond within small, medium and large scale. Cage size is varying from (1x2x1.5) for small, (3x5x1.5) for medium and (5x10x2) for large scale. It is made by bamboo and woods that floating in river, whereas pond size is varying from $\leq 500m^3$ (10x20x2.5) for small, 500 m^3 - 750m^3 (15x20x2.5) for medium and $\geq 750m^3$ for large scale.

Table 2, 3 and 4 shows about the costs and profitability of snakehead culture (excluding salary and wage of labor) in 2006, the average gross return of cage culture was USD 3,588 per cage per cycle, and USD 356 for pond system. Moreover, the study in 2011, indicated that the average gross return for cage culture was USD 4,811 per cage per cycle and USD 3,843 for pond system. Concerning

small and medium-scale cage, the average gross return was about USD 1,746 and USD 7,874 respectively, whereas for pond culture, there were USD 2,016 for small, USD 3,922 for medium and USD 5,892 for large scale. With regard to in study in 2016, the result shows that farmers cultured snakehead fish in cage system received gross return about USD 4,233 in average, while in pond system they could get average gross return approximately USD 9,750.

In 2006, the average gross profit of cage culture per cycle was USD 840 and for pond culture was USD 86. Regardless scale, in study in 2011, it reveals that the average gross profit of cage culture was USD 2,250 and for pond system was USD 461. This profitability varies depending on scale of culture operation. For cage system, the medium scale operation had high gross profit (USD 4,951.3 per cage per cycle), whereas the small-scale system reveals loss in terms of gross profit (USD -452 per cage per cycle). This might be due to the high expenditure on feeds and fingerlings which were generally bought at higher price than large-scale farmers. For pond culture, the gross profits for small, medium, and large scale were USD 238, USD 100, and USD 1,046, respectively. Based on the result of the study in 2016, the average gross profit of cage culture was USD 217. However, for pond system, the gross profit was lost (– USD 9,511) because of big expenses on feed cost.

In terms of net profits, showed that cage culture system seems had higher profitable than pond system, that is USD 570 per cage per cycle and USD 29 for pond per cycle. There was similar in 2011, which showed that the net profit for cage culture for the small scale turn to loss (USD -747), while medium scale was USD 4,353. For pond culture, the net profit for small, medium, and large scale was USD -153, USD -71, and USD 383 respectively. This implies that medium scale of cage culture and large scale of pond had more profitability.

In 2016, both cage and pond culture system showed that the net profit was negative. This may due to after lifting snakehead culture in Cambodia, there was many snakehead farmers in Cambodia lead to have surplus of snakehead production lead to have low price.

In Vietnam, snakehead culture was divided into different system; include pond, hapa in pond and hapa in river. For each group, the scale was divided by small-scale, medium scale and large scale. Each model and scale would be characterized by a corresponding system, including hapa in river for small-scale; medium scale for hapas in pond model and pond model was large scale.

The results from Table 6 showed that, small scale (hapas in river model) had an average volume of 56 m^3/hapa and stocking density of 129 ind/m^3. The FCR ratio was 1.42 (pellets feed) and 4.2 (small-size fish feed). The yield reached 32.5 kg/m^3. Production cost was 42.18 USD/m^3/crop, corresponding to 1.3 USD/kg and the selling price ranged 1.34-1.63 USD/kg. Revenue gained 43.48 USD/m^3/crop, corresponding net profit was 1.29-10.9 USD/m^3/crop. Rate of return was 3.1-25.8%.

Cost and profit analysis of medium scale (hapas in pond) from the Table 7 showed that, volume average was 61.5 m^3/hapa with stocking density of 94.2 ind/m^3. The FCR ratio was 1.32 (100% pellets feed). The average yield was 92.2-32.5 kg/m^3. Production cost/crop and per kg were 39.58 USD/m^3 and 1.36 USD, respectively. With the selling price ranging from 1.4-1.66 USD/kg, average revenue could be 41.0-53.8 USD/m^3/crop. Net profit was 1.42-9.76 USD/m^3/crop, equal to 0.05-0.3 USD/kg. Rate of return was 3.6-22.1%.

Turning to pond culture model (large scale), average volume was 3,861 m^3/pond with stocking density of 21.9-50 inds./m^3. The FCR ratio was 1.31 (100% pellets feed). The average yield was 16.2-30.0 kg/m^3. Production cost was 20.81 USD/m^3/crop, corresponding figure per kg was 1.20-1.30 USD/kg. Market price ranged between 1.23 and 1.33 USD/kg. Revenue and profit was 21.4-26.1 USD and 0.57-4.65 USD/m^3/crop (respectively) whereas profit per kg was 0.04-0.29 USD/kg. Rate of

return was 2.7-21.0% (Table 8). Financial efficiency by production scales (Figure 1) showed that, medium scale (volume 1,000-2,000 m^3) had the most profitable (USD 11.31/m^3) and production of 30 – 40 ton/hh.

Activity 2: Audience analysis: Sustainable development of snakehead culture in Vietnam

Seed production (broodstocks, nursing, quality): Available seed production systems and supply were very good, the famers were satisfied with quality and quantity of fingerlings (80% respondents). Participants said that nursing techniques resulted high survival rate (50-60%). Broodstocks tended to be bad quality at present time, thus, improving quality, especially genetic terms was proposed by majority of respondents (75%).

***Priority models and suggested scale*:**

In Cambodia, the model of snakehead culture system consists of 2 main system were cage in river, reservoir and lake and pond culture system. The culture system were divided into three categories, including small, medium, and large-scale. For cage culture system was determined that small scale ≤ (1x2x1.5 or 3 m^3), medium scale ≤ (3x5x1.5 or 22.5 m^3), and large scale ≤ (5x10x2 or 100 m^3), while pond size is varying from ≤ 500m^2 (10x20x2.5) for small, 2000m^2 -750m^2 (15x20x2.5) for medium and ≥ 750m^2 for large.

In Vietnam, diversified models of snakehead in the MD were clarified, including hapa in river; hapa in pond, pond, tank, etc. Participants said that each farming model had curtained both advantages and disadvantages. Specifically, the small-scale hapa in river model was relatively suitable for the poor (76% respondents). Each farm should operate 2 hapas which resulted in the most profitable. In hapas in pond model, medium scale should be tackled to improve household economics. Whereas the pond culture model was suitable for large scale investment toward an industry-oriented snakehead culture sector. However, unstable market price has been a significant disadvantage of such scale.

Farming technique: Advanced science and modern technology have been applied for snakehead farming model i.e. VietGAP and circle water culture model. Lack of certification standards and best practice in snakehead culture were a problematic.

Feeds and drugs/chemicals: Cambodia during dry season (October to May) the most important source of feed were freshwater small-sized or low-value fish, while low-value or small sized marine fish species are used during rainy season (June to September). Many types of chemicals were used for snakehead culture. For Vietnam there are also many types of feed and chemicals supply for snakehead culture farming. However, there is no specific feed and chemicals for snakehead as well as lack of food and chemicals quality control method (85% respondents).

Environment & diseases*:* For environment issue, both Cambodia and Vietnam tends to degradation resulted in industrialization and intensive agricultural production, including snakehead culture. Diseases of snakehead appeared more frequently and more difficult to treat (i.e.. white disease). Need more training on disease prevention and treatment for snakehead culture famers from the authority was desire from farmers.

Markets (domestic and export)*:* Cambodia farmers has poor/lack of market network/information, lake of cooperation with each other, lack of information on market price and also the market challenges with the fishes import from Vietnam. For Vietnam the mainly market of snakehead was consumed domestically in Binh Dien wholesale market (70% of output), local markets, supermarkets, and processing agencies (dried and salted products). A small output of snakehead is exported to Cambodia.

Raw materials for processing and processing technique: Both Cambodia and Vietnam, raw fish was provided sufficiently for processing agencies, but the quality was not uniform/standard. Processing technology has still under modernization, products are not diversified and lack of added value products.

Distribution channels: There were about 40% of snakehead production was consumed in the MD and 60% was consumed outside of the region.

Market price: Selling price was unstable. The results from Figure 2 show that selling price on market fluctuated sharply throughout months and years.

Planning: There is no detailed planning on the area of snakehead culture that lead to difficulties in determining quantifies production. It is necessary to make detailed statistics on the area and output of snakehead culture to regulate supply and demand of the market. That is prevent the price dropping so low that fish farmers lose profit (90% respondents).

***Investment from government and private sector*:** Lack of synchronous investment by the state in infrastructure for snakehead culture farming. There should be incentives for private investment in snakehead supply chain (60% ideas from participants).

***Extension*:** Participants said that the extension system is very good (90% ideas). However, experience of expertise does not meet the demand for technical support to the famers. Therefore, it is necessary to improve the level of expertise for local extension.

***Labors*:** Labor in rural areas is abundant and the famers had satisfactory about labors for demand snakehead culture. However, there is a lack of skilled labor in pathology in snakehead culture.

Production cooperation: In Tra Vinh province, there is a cooperative between snakehead farmers and processing company that shows efficiency. It is necessary to build a model linking farming - processing and consumption as well as branding for snakehead.

Activity 3:

1. ***Policy briefs-Main focus on:***
    a) Policy Brief_Impact of Climate Change on Snakehead culture in Cambodia- Translate in Khmer
    b) Developing sustainably small scale snakehead farming to improve nutrition and income for the poor in rural area;
    c) Improving the quality of broodstock and fingerlings for disease and climate change adaptation, orientation to sustainable development;
    d) Encouraging investment in feed processing technology for snakehead;
    e) Improving current policies to develop snakehead following the chain linkages and building the trade mark globally in the future.

2. Guidelines/best practices: best practices documents on sustainable snakehead aquaculture: recommendations for best practices of snakehead pond culture

- The stocking season should be from September to October.
- Good ponds average size is 1,000-2,000 m^2
- Farms should take area for waste treatment.
- Stocking density: 40-80 Inds./m^2.
- Pellets feed: 40-42% protein
- Controlling FCR at 1.2-1.3

- Local workers and the poor should be priority in large-scale farming
- Farming period/crop: 6-7 months

3. Poster

- Genetic diversity of striped in Cambodia.
- To deliverable dissemination of sustainable development of snakehead culture in Vietnam.

4. Leaflet

- Enhancing food security and household nutrition in Cambodia.
- Guidelines and policy suggestions for sustainable snakehead culture and management of aquatic resources in Cambodia and Vietnam

5. Factsheet

Policies to support the sustainable development of snakehead culture in the MD.

Activity 4: Communication and dissemination strategy

The products of the project have been transferred to related parties for propaganda purposes of project on "Guidance and policy recommendations for sustainable snakehead aquaculture and aquatic resource management in Cambodia and Vietnam".

The following audiences: (i) Snakehead feed; (ii) Snakehead feeding strategies; (iii) Processing and value-added products for women; (iv) Improvements in the trade and value chain for both capture and culture fish in the region; (v) Human nutrition and human health impacts of fish; (vi) Wild and hatchery-stocked brooders of snakehead stocking and conditioning; (vii) Snakehead breeding, weaning, and rearing/grow-out; (viii) Economics of production.

DISCUSSION

The results of cost and profit analysis in Vietnam showed that the small-scale model of snakehead culture was suitable for the poor with aim to improve nutrition and used idle labor of household to improve income. Low financial investment and low production risk are favorable conditions. The profit in that case could reach 5.6-7.6 USD/m^3/crop (Chung and Sinh, 2011). While the model of medium-scale snakehead farming is more economical requirement and suitable for farmers with their own economic potential. Investment in such snakehead farming could result a farmer's livelihood improvement. The medium-scale model might bring the profit of 50-60 USD/m^3/crop (Thuy and Loc, 2015). Large-scale model (snakehead culture in pond) requires higher investment in financial terms than others model. However, such model could bring the highest profit among these models. According to Hien *et al*., (2012), snakehead pond culture had profit around 13,869 USD/ha/crop. Whereas Grimm-Greenblatt *et al*, (2015) indicated that small-scale farms using small-size fish (SSF) entirely had smaller fixed cost and greater variable cost than that of farms using pellet at the same scale. The high productivity farms (large-scale) using pellet had more beneficial than the farms using small-size fish (via the NPV and IRR indicators) and would continue to have higher economic benefit if moving to pellet. Low and medium productivity farms were more beneficial when using small-size fish (Grimm-Greenblatt et al, 2015). However, pond model has high risks and low profitability with only 37.5% of households being profitable (Navy *et al.,* 2016). Main difficulty of snakehead culture was dominant domestic consumption whereas finding stable markets internationally is a challenge. Snakehead price much depends on season, species and distribution channel (traders could put pressure on prices) (Chung and Sinh, 2011). Farmers lack capital for production while loans accounted for 50% of the capital requirements for production (Thuy, 2010). Accessibility to capital of farmers is also limited, this circumstance prevents residents take part in snakehead production (Loc, 2015). Development orientation of snakehead culture in Vietnam was proposed as below:

- Gradually reduce the amount of fish oil and fish meal in diets with soybean meal, rice bran or wheat bran (Navy *et al*., 2016).
- Replacing marine fish or golden snails in diets when freshwater small-size fish dropped (Thuy, 2010).
- To improve the quality of snakehead seeds, during nursing and breeding snakehead seeds, need to pay attention to sparse fingerlings in order to limit fish distribution that leads to eat together (Sang *et al.,* 2013).

CONCLUSIONS

In Cambodia, medium-scale snakehead culture system had the highest profit compared to small-scale culture system and also better than pond culture practice in both Cambodia and Vietnam. Cost and profitability of snakehead during 2006, 2011, and 2016 in Cambodia, indicated that the net profit of snakehead cage culture in 2006 was higher than the pond system, USD570 and USD 29, respectively (Table 2). Compared to the result in 2011, it shows that medium scale snakehead cage culture had highest profit (USD 4,353) compared to small scale. For large scale pond culture it was revealed that had profitability of USD383, whereas small scale and medium-scale farmers had negative profit (Table 3). Moreover, based on the results in 2016 it shows that the net profit was negative value for both snakehead cage and pond culture system, (-USD336) and (-USD11,491), respectively. This may be due to lifting of the ban on snakehead culture in Cambodia and have many snakehead farmers and surplus snakehead production. Similarly, the result was seen in Vietnam during the two-year study interval (2011 and 2016) that the bigger size pond culture system is the higher profitability system for farmers. The economic efficiency of pond culture system by production scale shows that small-scale pond culture farmers (<1000m2) received profit about 10 USD/m2/crop, while medium-and large-scale culture (>1000m2) received 60 USD/m2/crop.

In Vietnam, small-scale snakehead farming is properbly a feasible farming economic activity to the poor in rural area with the aim to improve nutrition and seafood consumption. Pond culture is a popular system for the households with financial potential in the form of high comercial industrial. Relevant stakeholders have stated that the quality of snakehead fingerlings tends to deteriorate. Therefore, consideration to the quality of broodstock in accompanied with investment in order to improve quality of seed is an urgent solution. Diseases in snakehead fish farming model appeared regularly together with incurable treatment. Selling prices fluctuated within year and drop significantly in 2016 and 2017. Stakeholders proposed that the public sector, especially government's support should take into account, especially export promotion to improve market prices.

It can be concluded that the major contributor to inputs cost for both cage and pond culture system in Cambodia and Vietnam derives from high feed cost. As clearly seen in the results of the study in Cambodia, the highest costs for snakehead cage and pond culture operation came from fish feed which contributes about 81% for cage and 75% for pond of total variable cost in 2006. Feed cost in 2011 makes up 88% and 49.37% for small- and medium- scale cage culture, respectively, and 53.48% for small, 69.54% for medium and 65.32% for large scale for pond culture. The share of variable cost from feed was still the largest cost in pond culture system which made up of 91% and 52%.

Therefore, it implies that the main factors for determining the profitability of snakehead aquaculture in both Cambodia and Vietnam are feed expenses and size of culture system operation. This call for attention from the relevant government institutions and agencies to provide support in terms of technical know-how and finance to develop/make pond and cage culture more productive and profitable and create employment opportunities for the rural poor. By promoting snakehead fish farming, it is hopefully expected that snakehead culture can, first, be used to sufficiently complement or replace wild snakehead fish which is decreasing, and, second, lower the price of fish to fit people's

household income to guarantee that not only rich people but also the poor people can access to fish, particularly snakehead.

QUANTIFIABLE ANTICIPATED BENEFITS

The project has developed the best practice for snakehead culture in the pond model, which helps for snakehead farming to calculate their financial ability for investing. In addition, it helps increase economic efficiency and reduce risk in production.

The workshop training were carried out at An Giang, Tra Vinh provinces and final at Can Tho University for 141 scientists, researchers, resource managers, government officials, and non-government organizations and feed mill in Vietnam were better informed on the development of sustainable snakehead aquaculture through research based guidance on feeding, breeding, weaning and rearing/grow-out.

500 snakehead farming households in Cambodia will be better informed on the development of sustainable Giant snakehead aquaculture through research based guidance on feeding, breeding, weaning and rearing/grow-out.

Training on seed production, grow-out and fish diseases prevention and treatment for women at three provinces of An Giang, Dong Thap and Tra Vinh 106 participants in snakehead aquaculture in Cambodia and Vietnam will be better informed on the development of sustainable snakehead aquaculture through research based guidance on feeding, breeding, weaning and rearing/grow-out and on post-harvest activities including processing.

This investigation supported research activities of 1 master and dissertations of 2 undergraduate students (2 female).

Four research at CAF, CTU in Vietnam were trained and have experience on using economics to analyze specific impacts of cost and profitability of snakehead culture.

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TABLES AND FIGURES

Table 1. Number of participants in workshop-trainings of audience analysis in Cambodia

Stakeholders	BattamBang	Kampong Thom	National	Total
1. Farmers (small, medium, and large scale)	11	12	30	63
- Women	5	5	5	15
2. Private sectors	**8**	**10**	**18**	**36**
- Hatchery/nursing	0	0	1	1
- Feed and chemical company	2	2	2	6
- Processor	3	4	7	14
- Traders	3	4	8	15
3. Government officials	**12**	**12**	**25**	**49**
- Aquaculture + Fisheries Officers	2	2	5	9
- Researchers + Policy makers	10	10	15	35
- CTU-Vietnam	0	0	5	5
Total	**31**	**34**	**73**	**138**

Table 2. Cost and profitability of snakehead culture in cage and pond in 2006 in Cambodia.

Species: Giant Snaked Head	Total value per year/cycle (USD/Year)	
Items	Cage (n=9)	Pond (n=9)
I. Gross return	**3,588**	**356**
A. Total VC	2,748	270
B. Total FC	270	58
II. Total costs (TV+TF)	**3,018**	**327**
III. Gross profit (I - A)	**840**	**86**
IV. Net profit (I - II)	**570**	**29**
V. Real Profit (IV - Salary)	**225**	**-39**

Table 3. Cost and profitability of snakehead culture in cage and pond during year 2009- 2011 in Cambodia.

Species: Giant Snaked Head	Total value per cage (USD/Year)		Total value per pond (USD/Year)		
Items	Small (n=27)	Medium (n=15)	Small (n=24)	Medium (n=4)	Large (n=5)
I. Gross return	**1,746**	**7875**	**2,016**	**3,922**	**5,892**
A. Total VC	2,198	2,880	1,778	3,822	4,846
B. Total FC	295	642	392	171	663
II. Total costs (TV+TF)	**2,493**	**3,522**	**2,169**	**3,993**	**5,509**
III. Gross profit (I - A)	**-452**	**4,995**	**238**	**100**	**1,046**
IV. Net profit (I - II)	**-747**	**4,353**	**-153**	**-71**	**383**
V. Real Profit (IV - Salary)	**-835**	**3,959**	**-253**	**-267**	**89**

Table 4. Cost and profitability of snakehead culture in cage and pond during year 2016 in Cambodia.

Description	Total value per cage per year (USD/Year)	
	Cage (n=3)	Pond (n=2)
I. Gross return	**4,233.33**	**9,750.00**
A. Total VC	4,016.67	19,260.63
B. Total FC	552.36	1,980.83
II. Total costs (TV+TF)	4,569.03	21,241.46
III. Gross profit (I - A)	216.67	(9,510.63)
IV. Net profit (I - II)	(335.69)	(11,491.46)
V. Real Profit (IV - Salary)	(547.36)	(11,978.96)

Note: Fixed Cost (FC)

a. Depreciation of cage and materials/equipment:

- *Cage = (Purchasing Price) / (Number of expected years using) (Assuming that the Salvage value is equal to zero)*
- *Materials & Equipment= (Purchasing Price) / (Number of expected years using) (Assuming that the Salvage value is equal to zero)*

*c. Interest on borrowed funds = (Borrowed fund * Interest rate per year)*

Table 5. Number of participants in workshop-trainings of audience analysis in Vietnam.

Audience groups	An Giang	Tra Vinh	CTU	Total
1. Snakehead farmers	**22**	**20**	**26**	**68**
The poor	5	5	5	15
Women	14	7	10	31
2. Private sector	**8**	**5**	**8**	**21**
Seed production and nursing	2	1	2	5
Feed/drug traders	2	2	2	6
Processing	2	1	2	5
Fish Traders	2	1	2	5
3. Managers	**15**	**15**	**21**	**51**
Aquaculture managers	14	14	12	40
Political makers/researchers	1	1	6	8
NGOs			3	3
Total	**45**	**40**	**55**	**140**

Table 6. Cost – Profit analysis of snakehead culture small scale model (Hapas in river)

Indicators	Value (n=60)
Volume (m^3)	56.0
Stocking density (ind./m^3)	129
FCR	1.42
FCR small-size fish	*4.2*
Yield (kg/m^3/crop)	32.5
Production cost/crop (USD/m^3)	42.18
Selling price/kg (USD)	1.34-1.63
Production cost/kg (USD)	1.3
Revenue/Crop (USD/m^3)	43.48
Net profit/crop (USD/m^3)	1.29-10.9
Net profit/kg (USD)	0.04-0.34
Rate of return (%)	3.1-25.8

Table 7. Cost – Profit analysis of snakehead culture medium scale model (Hapas in pond)

Indicators	Value (n=30)
Volume (m^3)	61.5
Stocking density (ind./m^3)	94.2
FCR	1.32
Yield (kg/m^3/crop)	29.2-32.5
Production cost/crop (USD/m^3)	39.58
Selling price/kg (USD)	1.4-1.66
Production cost/kg (USD)	1.36
Revenue/Crop (USD/m^3)	41.0-53.81
Net profit/crop (USD/m^3)	1.42-9.76
Net profit/kg (USD)	0.05-0.3
Rate of return (%)	3.6-22.1

Table 8. Cost – Profit analysis of snakehead culture large scale model (culture in pond)

Indicators	**Value (n=70)**
Volume (m^3)	3,861
Stocking density (ind./m^3)	21.9-50
FCR	1.31
Yield (kg/m^3/crop)	16.2-30.0
Production cost/crop (USD/m^3)	20.81
Selling price/kg (USD)	1.20-1.30
Production cost/kg (USD)	1.28-1.32
Revenue/Crop (USD/m^3)	21.4-26.1
Net profit/crop (USD/m^3)	2.26-11.31
Net profit/kg (USD)	0.04-0.29
Rate of return (%)	2.7-21.0

Figure 1. Workshop – Training on snakehead culture development sustainability based on audience analysis in Inland fisheries research and development institute, Phnom Penh, Cambodia.

Figure 2. Group discussion in Inland fisheries research and development institute, Phnom Penh, Cambodia

Figure 3. Workshop-Training on snakehead culture development sustainability based on audiences analysis in Kompong Thom province, Cambodia

Figure 4. Workshop-Training on snakehead culture development sustainability based on audiences analysis in Battambang province, Cambodia

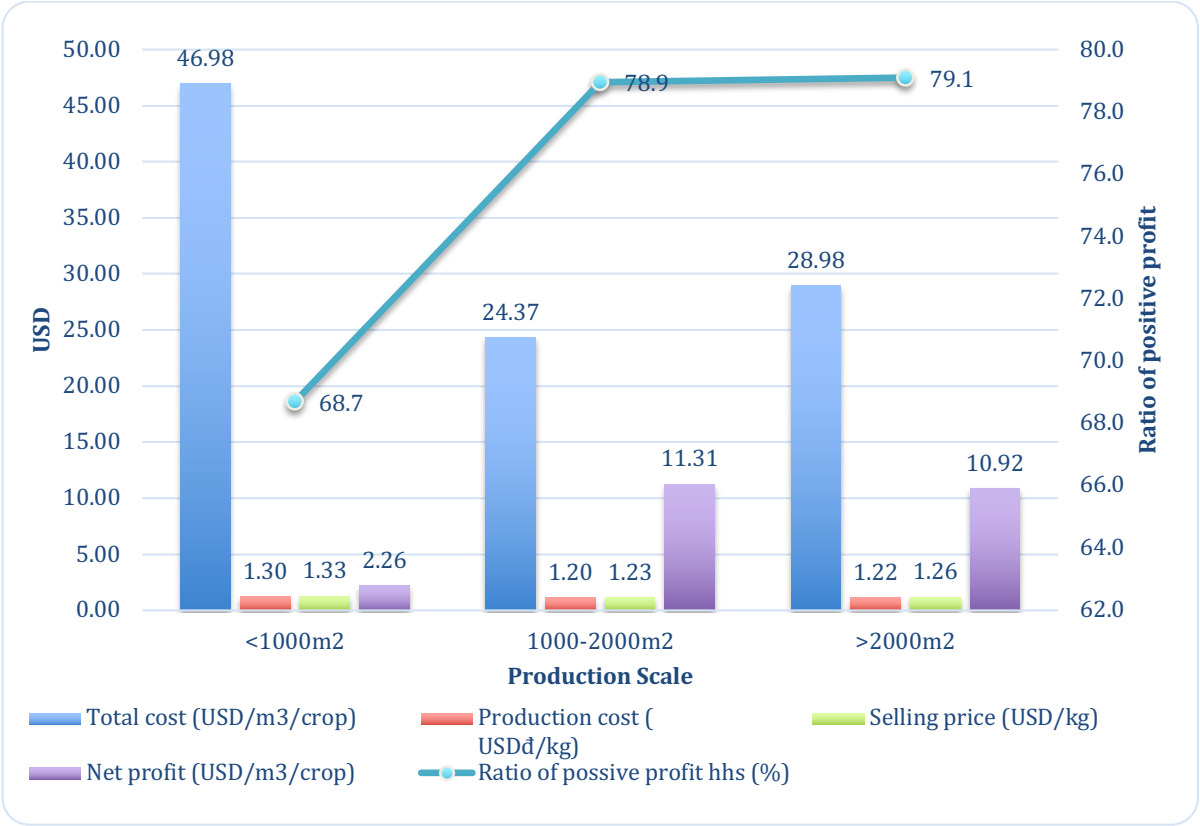

Figure 5. Financial efficiency by production scales in Vietnam.

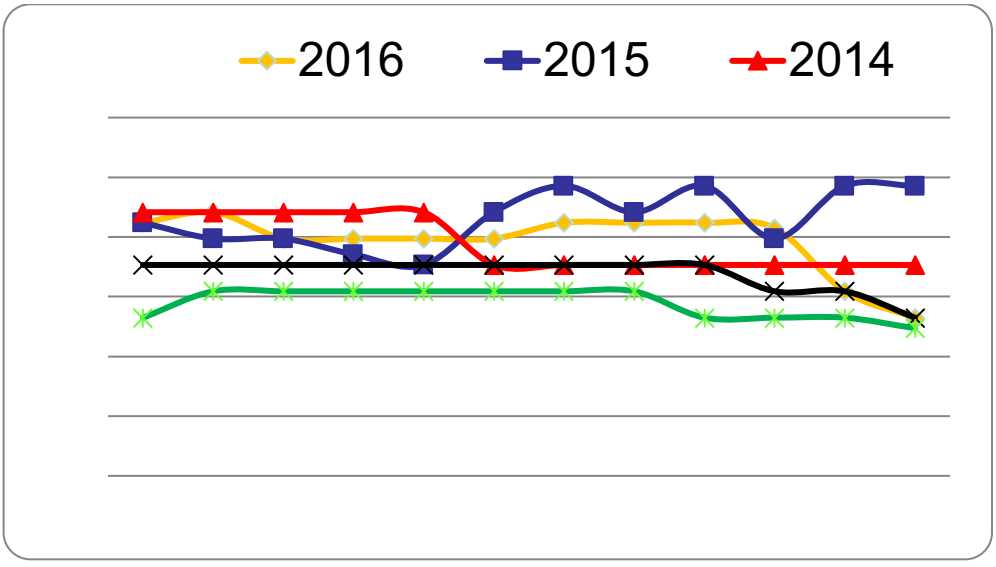

Figure 6. Selling price on market in Vietnam

Figure 7. Workshop – Training on snakehead culture development sustainability based on audiences analysis in An Giang prvince in Vietnam

Figure 8. Group discussion in An Giang province

Figure 9. Workshop – Training on snakehead culture development sustainability based on audiences analysis in Tra Vinh province

Figure 10. Group discussion in Tra Vinh province

Figure 11. Presentation result of group discussion in Tra Vinh province

Figure 12. Workshop – Training on snakehead culture development sustainability based on audiences analysis in Cantho University

Figure 13. Group discussion in Cantho University

Figure 14. Presentation in Cantho University

Figure 15. Participants attended on workshop in Cantho University