Aquaculture Innovation in Vietnam

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Top left: Pangasius (*Pangasianodon hypophthalmus)* pond harvesting
Top right: Pangasius (*P. hypophthalmus)* processing
Bottom left: Red Nile Tilapia (*Oreochromis niloticus*) feeding in cages
Bottom right: Giant tiger shrimp (*Penaeus monodon*) grading

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Management summary

Interviews with experts in the Pangasius, Shrimp, Tilapia and Mud Crab supply chains have been conducted in The Netherlands, Belgium and Vietnam to assess the current knowledge of constraints and innovation opportunities for further sustainable development of the aquaculture industry in Vietnam. The results of 32 interviews involving 13 experts from universities and research centres, 11 experts from the production and retail industry, 1 from the feed industry, 1 from the local government and 6 from smallholder producers contributed to answering two questions:

- What are the main constraints and threats for further development of the supply chains?
- What are the opportunities for social, environmental and economic sustainable innovations at different levels of the supply chain?

Main constraints and threats

The constraints and threats listed below are different per supply chain and there is a number of cross sectorial constraints shared.

Pangasius

-The lack of marketing strategy, coordination and negative publicity have damaged export markets, mostly in Europe and USA.

-Wastewater loaded with nutrients and pathogens increases the risk of pollution and disease transmission between farms.

-The poor quality of fingerlings results in very low survival rates between 6-10% and increases the production costs.

-Smallholder producers are increasingly excluded and replaced by big companies which affects negatively their livelihoods.

Shrimp

-The shrimp sector lacks a domestic broodstock program and is heavily dependent on foreign supply of seed and broodstock.

-Multiple viral and bacterial diseases constitute a permanent risk associated to intensification and limited capacity of smallholders.

-Smallholder shrimp producers which are the key actors contributing to the biggest part of the production are not adequately integrated in the value chain. They have limited capacity to improve their production systems, no direct access to markets resulting into low profit margins.

Tilapia

-Inefficient market approach and marketing of Tilapia, with a risk to repeat the mistakes of the Pangasius sector in the absence of an appropriate marketing strategy and rigorous coordination of the sector.

-Breeding programs of Tilapia are not sustainable as the sector relies on seed inputs from outside the country.

Mud crab

-The upscaling of the mud crab production is constrained by the lack of commercial feed and the labour intensity during grow-out.

-The sensitivity of mud crabs to vibrio's is critical during hatchery phase, resulting in high losses and economic damage.

Cross-sectorial issues

-Climate change with reduction of available freshwater in the Mekong River and salt intrusion in the Mekong Delta affects negatively food production in general and aquaculture in particular. Shrimp production is expected to become the most affected in comparison to other sectors as a result of projected fluctuations of climatic conditions.

-Feed constitutes the highest share in the production costs and is currently relying on fishmeal and fish oil, resources which are partly imported and expensive and therefore not sustainable in the future.

-The lack of coordination and spatial planning of the aquaculture activities are the major threat to the entire aquaculture sector and the cause of an environmental pressure.

-Smallholder farmers are not well organised and financed. This results in a slow adoption of best management practices and reduces access to quality seeds, processing facilities and markets.

-Water, system and disease management is not implemented beyond the farm level and needs the support of policies and investors. A lack of coordination at high level poses a high risk to farming operations.

Opportunities for sustainable innovations

Feed

Two of the most important farmed fish species in Vietnam, namely Pangasius and Tilapia, have low animal protein requirements in their diet. Fishmeal and fish oil in their diets can significantly be replaced by a range of alternative feed ingredients from plant origin, insects, microalgae, microbial proteins, seaweed which have a potential in the future provided that their price is affordable and the supply reliable. However, this co-exists with challenges for health and changes of markets. Feed should meet the nutritional demands of the fish farmed to overcome potential health issues.

Hatchery feed for Shrimp and Pangasius as much as commercial feed for grow-out of mud crabs constitute an investment opportunity as these types of feed are not available in Vietnam.

Breeding, hatchery and nursery

The development of national seed & broodstock management and breeding programs of farmed aquaculture species can contribute to improve the quality of seeds and accessibility to smallholders. Breeding for salinity tolerance (Pangasius and Tilapia) and disease resistance are two fields of interest to provide robust animals adapted to changing climatic conditions and improved resistance against diseases. The introduction of the RAS technology in hatcheries and nurseries can contribute to increased biosecurity and production of quality stocking material the whole year round. All these innovations are expected to have a very high impact to the sector.

Grow-out

Integration of production systems, the green water and the biofloc technologies, particularly in Shrimp and Tilapia production, offer certain advantages such as feed and nutrient recovery, health benefits but need a training of farmers in management of complex integrated systems. The use of removable covers in shrimp ponds contributes to reduced stress and disease outbreaks. These innovations are expected to have a very high impact to the production and disease control.

Post-harvest, processing and use of processing by-products

Added-value products are produced by processing of aquaculture by-products: dehydrated collagen and gelatin from Pangasius skin, hydrosylates, short peptides, fishmeal, bone meal, shrimp head meal, chitin and chitosan from shrimp processing wastes. This production technology is only available for single high end processors. Public-private processing units accessible to smallholder producers can contribute to the reduction of post-harvest losses and guarantee the quality and the safety of the products resulting in higher competitiveness, due to production cost reduction. The impact at this level is estimated to medium to high.

Marketing

The Vietnamese aquaculture sector has suffered in the past from a lack of a coordinated and inclusive market strategy. If no strategic changes are made at this level, the industry will further be hampered. Any kind of innovation in marketing, market development and consolidation, and high quality products will have an extremely high impact to the industry, irrespective of the supply chain and markets targeted.

Although constraints and opportunities are different per supply chain, strategy and long term vision are globally needed at different levels in each supply chain from production to market. Key priorities for intervention should be in: -a better coordination of the industry, -an inclusive involvement of smallholders into long-term development plans, -a sectorial and area-based management of resources, an improvement of the productivity and the quality of products, -a reduction of negative social and environmental impacts, -well tailored breeding programs, improved feed formulation and management, and coordinated disease management.

1 Introduction

1.1 Background

The Dutch Ministry of Economic Affairs contributes to sustainable development of the aquaculture industry in Vietnam through the organisation of a regional conference on food security and an aquaculture innovation competition in Vietnam.

For this purpose, the Ministry has addressed a “helpdeskvraag” to Wageningen University & Research, to make an overview of the knowledge already available around: -the main constraints and threats for further development of the industry and, -the future innovation needs with positive social, environmental and economic impacts in the sector.

Three main aquaculture supply chains “Pangasius, Shrimp and Tilapia” have been selected for investigation of constraints and opportunities for innovation at five levels of the value chain: breeding, feed, grow-out, post-harvest and marketing. The “mud crab” supply chain, a new developing sector, is also investigated aside this work.

The study contributes to further policy development of the Ministry on food security in Vietnam and Asia.

1.2 Objectives of the study

The aim of the study is to identify the main constraints and areas for future innovation in the aquaculture industry in Vietnam with a special focus on social, environmental and economic sustainability.

Specific objectives are to make an overview of the main constraints and threats to the Pangasius, Shrimp, Tilapia, Mud Crab supply chains and to highlight innovation opportunities for sustainable development in the sector.

1.3 Approach and methodology

The client has requested that his questions are answered by current knowledge available from experts and not by means of a new research nor by a literature study. For this reason, reference to literature is limited. Current knowledge reported has been gathered through interviews of selected experts in The Netherlands, Belgium and Vietnam. Interviewees include specialists from universities and research centres, feed industry, retail industry, representatives of producers and exporters of aquaculture and fishery products, officers of the local government and smallholders. In total 32 interviews have been conducted with 13 experts from universities and research centres, 11 from the production and retail industry, 1 from the feed industry, 1 from the local government and 6 smallholder producers. Three experts from the industry have declined the invitation for an interview. The study has been conducted by a team of two scientists from Wageningen University & Research (The Netherlands), one consultant from Ekolibrium (Switzerland) and one consultant from Fresh Studio (Vietnam). The different inputs have been compiled in a concept report and verified by two independent experts: a high level expert of the aquaculture industry in South East Asia including Vietnam and an aquaculture expert from Fresh Studio, Vietnam. During interviews, two questions were asked per supply chain: Pangasius, Shrimp, Tilapia, and additionally Mud Crab when the interviewees had information in this sector:

1. What are the main threats for further development of the supply chains?
2. What are the opportunities for social, environmental and economic sustainable innovations at the following levels of the supply chain: -breeding (hatcheries, nurseries), -feed with a focus on replacing fishmeal and oil as an ingredient, -grow-out, -post-harvest and use of fish/shrimp waste and, -marketing?

Because some respondents have requested anonymity, the names of interviewees and external reviewers are not reported. They can be linked under their consent in case of shared interests in business opportunities that may rise from this study.

2 Pangasius

2.1 Current challenges and threats

Different challenges have been identified.

Lack of marketing strategy, coordination and negative publicity

The biggest challenges for a sustainable development of the sector are very low market prices and further decrease of demand due to poor quality and reputation loss. Lack of coordination and excessive competition between producers affect the quality and the prices. Overall, there seems to be a lack of agreement between exporters in terms of a 'common strategy' to promote high-quality products. This has resulted in negative publicity damaging existing markets mostly in Europe and USA. Vietnam is still facing technical trade barriers such as anti-dumping duties on imports to the USA.

Better coordination could help to reduce these hindrances. The Vietnamese Government should take an active role with long term plans for the sector, to regulate the pond farming and siting, reduce the (over)capacity and improve the quality and the marketing. Initiatives like the "Pangasius your everyday fish" (http://youreverydayfish.com/) have contributed to marketing campaigns to give a better image of the fish in Europe. The Vietnamese Association of Seafood Exporters and Producers (VASEP), has among others, the mission to support members to improve capacity, quality and effectiveness in their business, to open markets and to strengthen competitiveness of Vietnam seafood products.

Water pollution with nutrients and pathogens

Along the Mekong River, waste water that is discharged from farms serves as water source for others, resulting in a continuous water exchange between farms. Apart from nutrients, this wastewater is also loaded with potential pathogenic bacteria increasing the risk of pollution and disease transmission. Without any appropriate action *Vibrio parahaemolyticus* found in shrimp farms can also erupt in Pangasius farms, according to experts.

There is a need for an environmental approach to solve problems of nutrient load and disease in the Mekong River basin and an overall rural spatial planning on a large scale of resources (water, space) use. Issues of waste water can be tackled by a combination of increasing feed efficiency by improving digestibility of feeds, a better feed management at the farm level and collection and treatment. A technical innovation has been introduced during the SuPa[1] project and consists of a hybrid system of recirculation aquaculture system (RAS) in ponds. Nutrients from ponds can also be recycled in agriproduction, such as rice/banana plantations and into bioflocs in Shrimp/Tilapia ponds.

Poor quality of fingerlings

Broodstock management is not good in most private hatcheries which do not have a standard production procedure and inbreeding is increasingly becoming a problem. Hatcheries manage brood stocks and produce fry based on experience. According to stakeholders, they care only about the quantity of fry produced and not about the quality, a fact that results in low survival rates from fry to fingerling after the fingerlings have been sold. According to a survey by RIA2[2] and CTU[3], the survival rate from fry to fingerling is only 6-10% for Pangasius. The government should take part in breeding programs in a public-private partnership model to improve brood stock management and the quality

[1] Establishing a sustainable Pangasius supply chain in Vietnam (SuPa)
[2] Research Institute for Aquaculture No. 2 (RIA2)
[3] Can Tho University (CTU)

of fingerlings on the market. It should also prevent the risk that access to quality stocking material becomes the privilege of big companies with exclusion of the smallholders.

Smallholder producers' exclusion

Compared to the early 2000s the number of small scale farmers in the Pangasius sector has declined significantly. Big companies are now consolidating the industry to control the over production by taking up small scale farmers. This has an impact on livelihoods but also on the production costs. Compared to smallholders owning their own business, seafood factories need to lease land and have to pay labour costs. This negatively affects the production costs. Small scale farmers are also marginalized by the system organization and have reduced access to markets. Large scale farms/processors possess agglomeration of big farms, contract farmers and have full control over production. Because of price instability, small farmers move in and out, shift easily to other species (Tilapia) and those who keep producing sell sometimes their fish at a loss. During the shifting period, the ponds are left in fallow unseeded for a season or more. This constitutes a latent or missed production opportunity for small scale farmers.

2.2 Opportunities for sustainable innovations and impact

2.2.1 Feed

There is still a lot of room for innovation in terms of feed formulation with care to reduce dependence on fishmeal and trash fish and to balance essential amino acids and fatty acids in diets. There are no official data of fishmeal consumption by aquaculture in Vietnam. Nguyen (2013) estimated that 3-20% fishmeal are included in Pangasius feed in Vietnam. Based on aquaculture production statistics and inclusion rates in various feeds, Hung and Huy (2007) have estimated this inclusion level between 3 and 5% fishmeal. The Pangasius industry is currently producing a lot of fishmeal by recycling its processing by-products.

2.2.2 Breeding, hatchery and nursery

Higher quality seed could help to increase the survival rate of fingerlings and reduce production costs. This can be achieved by better broodstock management, standardized production procedures at hatchery and nursery levels and research in high quality seed and fingerling production. The hatchery phase is conducted in tanks and the nursery is done in ponds. Despite high mortalities, farmers do the nursing in ponds because the investment in fry is very cheap (~1VND/larvae - 2VND/fry after hatching, June 24th 2016) and the production costs are very low (1-2% to produce 30g fingerlings in 90 days). Pangasius larvae feed on natural live food (incl. Moina sp.) in ponds for the first 10 days which contributes significantly to lower the production costs. Hatcheries are not much concerned by the low survival rates and the quality of juveniles (incl. disease carriers) as long as they can produce sufficient fingerlings.

Research done in the SuPa project in tanks has concluded that mortality can be reduced during the nursery phase in tanks instead of earthern ponds (0.1 to 2 ha). Survival rate averages 47% at 10 days post hatching in tanks (Caratis, personal communication). Indoor intensive hatchery production could be much more predictable and maybe even more cost-effective. Practicing the nursery phase out of ponds (current practice), for example in RAS tanks or flow through tanks, may contribute to improving the survival rate, increasing the stocking density, reducing the pressure on land and producing more robust fingerlings for grow out in ponds. Unfortunately we do neither have economic data nor proof for higher robustness in such systems which still need to be tested. In association to possible nursery in tanks, there is a market and a room for improvement in the starter feed development. Optimal feeding may contribute to reducing cannibalism in Pangasius.

Expected impact: medium to high.

Innovation in terms of new hybrids that are resistant to major diseases such as kidney disease would be welcome. Breeding programs are needed to develop salinity tolerant Pangasius and to increase its plasticity for aquaculture.
However, breeding programs for this species are disadvantaged by: 1) a long generation time, 2) a continuous shift in breeding priorities, 3) a selection for disease resistance complicated by the frequent change in type of diseases. Vaccination is the best strategy to protect the species against diseases. Hybridisation has contributed to increased resistance to diseases, salinity tolerance and better growth in other species and can be tried in Pangasius provided that there is a good systematic knowledge of wild species from different habitats.

Expected impact: medium.

2.2.3 Grow-out

There are three categories of Pangasius farmers: -big companies, -contract farmers with business relationships with big production/processing companies, and -small scale farmers with individual, family owned/operated farms. In contrast to shrimp farming (chapter 3), small scale Pangasius farming is no longer a peasant activity of poor households. It is often a full time activity involving an industrial process with a minimum of 80-100 tonnes of output per cycle. Small scale Pangasius farms are riskier than company farms because they do not have sufficient and appropriate resources. Nowadays original small scale farmers are working for the farmers who are connected with export companies or are retailers (of feed or chemicals).

Contract agreements with processing companies who supply feed and seed to farmers and later collect the fish, do not foster social development, as farmers are heavily dependent on big companies and their payment terms. Small scale farmers sell their fish to processors independently of the market price but because the buying processor is paying faster. In general, fish export companies, feed companies and retailers get the highest benefits. Small scale farmers do not have incentives and capacity to invest in optimization of production, water treatment and disease mitigation, consequently they risk to disappear in the future. There should be an alternative solution for such farmers.

2.2.4 Post-harvest, processing and use of processing by-products

Pangasius production and processing are dominated by big companies which are well organized and have European hygienic standards. However, there is room for innovation. So far, Vinh Hoan is the only company in Vietnam that is working on the production of dehydrated collagen and gelatin from Pangasius skin. Edible meat by-products are processed into meat balls, fishmeals used by feed industry. The Pangasius industry produces nowadays more fishmeal than it needs. Because these fishmeals are coming from best practices, they can be certified IFFO RS for the responsible supply of feed ingredients which is good for the marketing of Pangasius. Nonetheless, a lot of the fishmeals used for Pangasius feeds are still coming from overfished stocks. According to some stakeholders, some of the fishmeals produced from Pangasius by-products are reused to feed Pangasius.

->There is a need for more regulation upstream the chain.

Other Pangasius wastes are processed into bone meal or used in pork feed. Pangasius wastes can be used in tilapia, shrimp, poultry and pig feeds. Processing industry may make more profits in the future from the production of hydrolysates and short peptides, used in the nutrition of young piglets. Wastes from Pangasius processing are improving the profit of processing companies far beyond the margins of selling fish fillets. However, benefits from improvement in the value addition are not transferred to the farmers involved in production.

Moreover, smallholders have neither access to the cold chain nor to the commercial processing facilities. Their products can quickly deteriorate with the risk of bacterial contamination of the food chain. Central public-private processing units made accessible to smallholders can contribute to reduction of post-harvest losses in small scale producers. These units can be used to control and to guarantee the quality and safety of products.

2.2.5 Marketing

Value-added products can yield premiums and there is capacity in Vietnam for value-adding. However, there needs to be more marketing support for better communication. Value-added products are still marginal in overall sales.

In various Western media, concerns have been expressed about food safety and environmental issues related to the use of antibiotics and the pollution in the Mekong River which have challenged the Pangasius industry. The Pangasius sector has suffered further under the negative impacts of bad campaigning and low quality products (i.e. excessive glazing, phosphate treatment). Although there have been efforts to regulate treatment of products, quality is still low in many cases. There is a need for a clear strategy to stabilize the market price and ensure profits for farmers through optimised production processes through for example governmental management (standards or policy) such as controlling the quality and quantity of production. Otherwise, the sector risks to further decrease or totally collapse.

Because of the past bad image, it is hard to obtain a good price for certified Pangasius and premium Panga fish products. Certifications have failed at value-adding, with standards such as ASC and Global GAP being more a license to produce for Western markets. Certification of Pangasius products has only helped the product to remain on the market. We can expect the price of Pangasius to remain low in the future, because of its main unique selling point: a cheap product. Moreover, in Europe for instance, demersal fish captures are on the rise and quotas increase (e.g. cod, saithe and haddock have even become choke species in some part of the North Sea). These fish are direct competitors for the Pangasius industry. Marketing wise it will be difficult for the Pangasius to compete for a better price than fish caught in Europe in the coming years, according to an expert with experience in Vietnam and Europe.

Attempts to access niche and high end markets are not always successful despite different supporting initiatives (Brussels Seafood Exposition, Dutch Cooperation) to advertise the Vietnamese aquaculture products on the European market. Creative ways to enter new markets such as branding, niche markets or further value addition (f. ex. coating, flavoring,…) is one way to market innovation.

Expected impact: high.

There is a big domestic fish market in Vietnam as there are also different types of product quality and market segments. Low grade fish (too small/too big, not suited for export), Pangasius heads (in soup) from processing are also consumed locally. Backyard ponds and rivers are still supplying farmed Pangasius that is consumed locally contributing to food security. Although of good nutritional quality, the yellow fillet is consumed on the domestic market while the export market prefers the white fillet.

Large opportunities exist in improving the quality and safety of seafood sources in Vietnam. Seafood that is locally sold is usually of low quality products that can’t comply export requirements and therefore pose a risk to the health of consumers rather than it secures food availability. Fish consumed locally are poorly regulated and locals become more and more aware about the health issues regarding the fish/shellfish they consume, notably after the recent discharges of toxic wastes from Formosa steel plant that killed tons of fish and devastated fishing communities along Vietnam’s central coast.

3 Shrimp

3.1 Current challenges and threats

Giant tiger shrimp *(Penaeus monodon)* and Pacific white shrimp *(P. vannamei)* are the main cultured species stocked at low to high densities. Giant freshwater prawns *(Macrobrachium rosenbergii)* are also stocked during rice cultivation at low stocking densities (1 to 2 prawns per m^2) with some feeding.

Giant tiger shrimp seed production is concentrated in the Mekong Delta at small-scale hatcheries. Pacific white shrimp broodstock are mostly imported from other countries (USA, Thailand and Singapore) and their seed production is concentrated in the central provinces at large hatcheries (Hai et al., 2015).

Recently, the majority of intensive shrimp farms shifted from farming the giant tiger shrimp to Pacific white shrimp introduced in 2000 because of the white shrimp's advantages of rapid growth, high stocking density and high productivity. Stocking densities are greater for Pacific white shrimp (70-150/m^2) compared to giant tiger shrimp (20-35/m^2). Pacific white shrimp are harvested after 90-100 days, yielding 10-15 MT per hectare per crop. Giant tiger shrimp are harvested after 100-150 days, yielding 3-7 MT per hectare per crop. Pacific white shrimp culture with biofloc technology uses even greater stocking densities. In 2015, a super-intensive shrimp farm operated by Viet Uc company with aeration and stocking densities ranging between 400 and 900 post-larvae per m^2 has successfully produced 60 to 80 MT of shrimp *(P. vannamei)* per hectare per crop in plastic-lined ponds in 3.5 to 4.0 months (Hoang, 2015).

There are however different challenges at different levels.

Seed import dependence

The biggest threat to the Vietnamese shrimp sector lies in the heavy dependency on supply of high quality seed and broodstock from outside of Vietnam. Although hatcheries have been professionalized over recent years with the development of very big and professional hatcheries, the same has not happened with a domestic broodstock program. There is no high quality domestic broodstock available and hatcheries depend on inputs from major suppliers outside of Vietnam. Quality broodstock selection and development requires a long-term effort that takes at least eight to ten years and Vietnam will thus continue to be heavily dependent on supply of quality seed and broodstock for yet some time.

Diseases

White spot viral diseases and *Vibrio parahaemolyticus* bacterial diseases (initially called EMS: Early Mortality Syndrome) have erupted in shrimp farms in the past and still constitute a risk. Diseases were caused by drastic changes in the culture environment by disinfecting the ponds by liming. This practice killed all the microbes including the good microbes. Opportunistic pathogens (e.g. Vibrio's) are the first to colonize and dominate disinfected ponds. In Vietnam, the practice to fight this disease has been rather the massive use of antibiotics.

Marginalisation of smallholders

Shrimp production is largely dominated by thousands of smallholders in opposite to Pangasius industry. 90-95% of the area devoted to penaeid cultivation in the country are operated by smallholders (~65% of the production volume). Various levels of intensification exist and include: 1) integrated mangrove-shrimp (extensive) culture systems, 2) improved extensive systems, 3) semi-intensive systems, and 4) intensive systems. Small scale farmers without lands grow shrimp in intertidal ponds. These ponds cannot drain completely and their soils are not oxygenated. Intensive commercial farms establish their farms on land and pump water into ponds before stocking and water

is drained by gravity at harvest. Their soils are better oxygenated than those in intertidal zones. Small scale farmers do not have the capacity to invest in better systems. These farmers have no water treatment ponds, nor water storage ponds.

From a production and improvement support perspective the biggest threat is the ignorance of the thousands of smallholders that are key to the overall shrimp production in Vietnam. Unfortunately, the focus of improvement programs and the buyer markets are generally focusing on the very large processing companies that dominate the shrimp export in Vietnam while failing to see that these companies heavily rely on constant supplies from smallholders.

It has further been pointed out that there is an uneven and unfair distribution of costs and benefits between different actors along the value chains which might challenge a sustainable development of the sector. While production occupies thousands of small scale farmers, trade is controlled by collectors and middlemen. Value chains should be shorter and more transparent. This could be achieved by directly linking farmers with processors and processors with buyers. It is possible to improve the profit margins of small scale farmers by direct access to markets by integrating intermediate middlemen in the chain. Apart from these middlemen not many people take the risk to lend money, feed and seeds to smallholder farmers, especially the processors. This constitutes the main bottleneck for inclusive and sustainable value chain development involving small scale shrimp farmers. We could not obtain information about the existence of potential cross-sectorial financing schemes.

3.2 Opportunities for sustainable innovations and impact

3.2.1 Feed

Some interviewees have indicated the lack of correct feed for the hatchery and the nursery phases which constitute an investment opportunity for feed companies.

3.2.2 Breeding, hatchery and nursery

The Vietnamese shrimp sector is heavily depending on the supply of high quality seed and broodstock from outside of Vietnam. There is a need for a high quality broodstock selection and development program. This requires a serious and long-term effort since it takes at least eight to ten years to select accordant broodstock. Until then, Vietnam will continue to be heavily dependent on supply of quality seed and broodstock which is a serious risk to the industry. Attempts made in the past by some companies to develop their own genetically improved broodstock have failed. Several other companies are running shrimp breeding programs in Vietnam, especially in the Phan Rang and South of Nha Trang areas. Reasons of failure should be investigated to draw lessons learned. Overall management might be the main cause of failure.

Furthermore, there is a need for better transparency with traceability for available seed. There is a lot of variation in growth rate between animals and breeding programs should target a standardized growth. Presently EMS is the most challenging bacterial disease but there are already and will be many other diseases in the future, both viral and bacterial. There is a need for selection and breeding programs for multiple disease resistance. Since breeding for disease resistance cannot target each disease, efforts should be made on making animals and the production systems more robust. Robustness of animals should be gained naturally and not from feed supplements as currently practiced. Resilient systems are the way to go forward and RAS is one part of (many) solutions as there is no single solution to tackle all problems. Biosecurity requires systems to control what comes in and what goes out of production systems.

Expected impact: very high.

3.2.3 Grow-out

On grow-out level there is a lot of room for improvement of the sector. Focus should be on optimized production while reducing negative environmental and social impacts.

On one hand, there needs to be support for the thousands of smallholders that are key to the overall shrimp production in Vietnam. Their production systems are generally not very-well developed and many of them do not manage their production well. Yields are accordingly low. Better trainings and alternative farming methods can help increasing productivity while reducing negative environment and social impacts.

Techniques of “green water systems” have been imported from the Philippines and used by big farms to biologically treat the water before use in shrimp ponds. Philippino farmers check the good balance of zooplankton/phytoplankton in the green water reservoir. Tilapia are stocked in plankton/bacteria rich water to produce a water quality type which prevents bacteria and virus to dominate in shrimp ponds. Small scale farmers which constitute the majority of shrimp producers in the Mekong Delta do not have the capacity to implement this practice. Those who lack space can put hapas with Tilapia inside in shrimp ponds. Farmers who have space can use a first pond with seabass that predate on crabs and other disease carriers.

Shrimp are sensitive to sudden changes in water quality due to fluctuations in climatic conditions (temperature, salinity, dissolved oxygen). Heavy rains are followed by high mortality of shrimp. Rain water cools down the ponds and dilutes the brackish water. Recent developments have introduced removable covers for ponds. This reduces the impact of heavy rains changing temperature, salinity and DO of the water, which stress the shrimp and enhance disease outbreaks. Depending on the weather, covers are removed during sunny days and put back during rainy period and in the night. This practice is becoming popular in shrimp culture but need improved design for upscaling as only small narrow ponds can be covered. There is an opportunity in pond system redesigning and roofing for new farms to produce shrimp the whole year around also during the rainy season. Some shrimp farms in Bac Lieu and Quang Ninh provinces have already adopted roofed systems. Large scale farms without roofs do one crop per year during the dry season instead of 2-3 crops per year which are possible with roofed systems.

Expected impact: very high.

On the other hand, production in general should be optimized. New technologies such as biofloc recirculation systems or optimized aeration have shown to increase productivity enormously. However, investment and the cost of energy for aeration prohibit small scale farmers to take up the technology. Systems which require low investment costs and are energy efficient with less aeration costs are needed. The biofloc reactor system is interesting in hatchery phases and might not be appropriate in grow-out phases because the management is not easy at large scale. Currently biofloc production is manageable at small scale but upscaling can lead to difficulties to have a stable reliable manageable system. Nevertheless, the biofloc technology needs to be promoted on a large scale and further developed. Some big companies are already seeking foreign expertise or doing research on this technology to solve current constraints.

Bioflocs recycle part of wastes from (shrimp) aquaculture, contribute to the reduction of feed costs, improve water quality, reduce water effluents and control pathogens. Research conducted at Ghent University has shown that shrimp grown in biofloc systems with *Bacillus sp*. protect shrimp from viral and bacterial infections. However, since nobody has full quality control of the system, the big risk with bioflocs is the possibility to feed farmed organisms with pathogens in case the biofloc would be contaminated by pathogenic bacteria. It is important to understand the microbial systems and to characterize the features of bioflocs that have a positive effect on animal health and performances. Research should collect sufficient data to have more predictable systems and integrate this knowledge in designing new production systems.

Innovation opportunity exists also in integration of shrimp with tilapia and algiculture to increase the sustainability of shrimp culture. A new approach of integrated farming of shrimp with tilapia, microalgae and seaweed has shown positive results in disease prevention and nutrient recovery. Diagnostics showed that integrated shrimp ponds had *Vibrio parahaemolyticus* but no shrimps were diseased. A PhD research at Ghent University has found a 100 % phosphate recovery and economic benefits by integrating a nutrient flow from a fed shrimp pond to a tilapia pond and then a microalgae production unit. With the University of Hue, integration of rabbit fish (*Siganus guttatus*), a herbivorous fish species, with shrimp in lagoon ponds has already shown economic benefits of integration. This fish species fetches good prices on the market.

Producers are usually more interested in (intensive) monoculture systems for their ease to manage and to make quick profits. Integration of production systems has long term health and environmental benefits but possibly negative impact on revenues (economic benefits) on short term. In order to adopt new practices of integration instead of monoculture systems, a multi-stakeholder approach can bring changes but there should be policy support and financial incentives or tax reduction on land/water use to compensate for the possible loss of revenues. This is also true for mangrove restoration and eco-agriproduction integrated with shrimp farming. A pilot research project in the Mekong Delta can demonstrate the positive impact of production integration on feed recovery, environmental and health benefits as well as possible economic benefits and be used to train farmers in management of complex integrated systems.

Expected impact: very high.

3.2.4 Post-harvest, processing and use of processing by-products

Most shrimps are sold as unprocessed (unpeeled). For those processed, there is innovation need to valorize wastes from processing. Potential valorization of these wastes exist into chitin and chitosan production and in soil improvement. Shrimp skins are a highly desired products for chitin production and 100% of 'skin wastes' are sold into this production channel. Chitin, chitin nanofibrils, chitosan and other high value products derived from crustacean shells can be used for the animal feed and other industries (packaging, medicine,..). Shrimp soluble hydrolyzed products are used in a range of animal feeds but need to be certified. Shrimp head meal and side processing products are tested in poultry feed trials. A broad inventory needs to be done for further applications, bio-based materials, etc.

3.2.5 Marketing

Shrimp are produced in the South near the shores and have no market problems although there is no market strategy like other aquaculture supply chains. The sector takes benefit from a high demand from the market exceeding supply. Three main sources of shrimp to the factory are the small farmers, the middlemen and the factory farms. The quality is acceptable, the product is treated properly and moved fast in bags with ice. However, because of distances from the factory and high ambient temperature, quality of shrimp produced in smallholder farms can be compromised before reaching the factory. Marketing is not very advanced and based on market demand has mostly focused on promoting globally accepted standards (e.g. BAP, Naturland organic, ASC) by individual processing companies. Unfortunately, such standards will fail to integrate the thousands of smallholders which are the backbone and thus the real potential of the Vietnamese shrimp market. Marketing activities should target at integrating these smallholders and promote the Vietnamese shrimp market as a whole. This could be achieved by creating 'eco-regions', for example Ca Mau province which is one of the main supplier of Vietnamese shrimps. Focusing on integration of different stakeholders into one regional marketing (and certification) scheme would strengthen the area as a whole and support the further professionalization of the sector with accordant benefits for the economy, local livelihoods and the environment. In general, there should be more support for marketing.

Expected impact: high to very high.

4 Tilapia

4.1 Current challenges and threats

Inefficient market approach and marketing

Although Tilapia has been farmed in Vietnam for decades, the export-oriented Tilapia sector in Vietnam is young. It has been pushed by big companies that had a background in Pangasius farming. While Tilapia has been seen as an opportunity, the biggest risk to the young sector is wrong assumptions about the Vietnamese potential and knowledge about the Tilapia market worldwide.

Regardless of this situation, the Vietnamese government has been very quick to make big plans about potential of the Vietnamese Tilapia market with very ambitious plans that have been communicated widely, creating pressure on stakeholders having to deliver. However, the plans of the Vietnamese government are based on ambitions that have no good rationale and which are not founded on knowledge and expertise in the Tilapia sector.

If marketing and development of the sector are not coordinated, the Vietnamese Tilapia sector risks to undergo a similar faith as the Pangasius sector did, namely that achievements do not meet expectations and that lack of quality will soon pose a risk for the unique position that Vietnam has in the global Tilapia market.

Breeding programs not sustainable

Hatcheries use different strains which are not improved. As a typical practice of shifting from one to another species and constant change of focus, it has been difficult for the industry to have sustainable breeding programs. Although the goals of breeding programs are not clear, first preference goes to red tilapia (high end export market) and not to black tilapia (for the poor, domestic market). Farmers are not always willing to pay for good breed nor hatcheries are able to maintain pure lines. There is a need of governmental support to broodstock management and management of breeding infrastructures.

4.2 Opportunities for sustainable innovations and impact

4.2.1 Feed

Feed supply reflects the overall situation in aquaculture feed in Vietnam. While some integrated operations have their own feed production, others depend on feed from different supplies (domestic and import). There is still a lot of room for innovation in terms of feed. Hung and Huy (2007) have estimated between 3 and 5% fishmeal in Tilapia feeds. Fishmeal contents can be reduced significantly with accordant formulations and replacement through plant and other source based proteins combined with phosphorous.

Estimated impact: medium.

4.2.2 Breeding, hatchery and nursery

Hatcheries are heavily underdeveloped. Producers (farms) buy fingerlings according to availability. Mostly, these fingerlings are imported or come from nurseries located in neighbouring countries (e.g. Thailand, China). All these fingerlings lack a proper quality control and availability is very dynamic. Hatcheries and nurseries may have very different quality criteria than collectors, middlemen and retailers. Hatcheries would focus on survival, collectors and middlemen on fish that can tolerate high stocking densities during transport, and retailers on the color of the fish, etc. This may be one of the

reason why national breeding programs fail in Vietnam for various reasons (e.g. RIA with GIFT). Authorities seem to lack of understanding on what the farmers really need in term of breeding improvements. They just copy from another country and paste on Vietnam.

There is no proper broodstock selection or breeding program and Vietnam is heavily dependent on inputs from outside the country. An Giang Fishery Center had tilapia broodstock obtained from Ecuador. RIA2 had 12 ha of ponds devoted to selection program and several genetic programs. They were involved in the GIFT project and preserve a family of GIFT tilapia received from WorldFish. They also have tilapia broodstock from Israel, Ecuador and Indonesia. Whether the different strains remained pure is not known.

Research is needed to develop breeding programs of red tilapia farmed in the South in cages and of black tilapia in the Northern part of the country. With the salinization of the Mekong Delta, selection of saline tolerant tilapia is welcome. There are tilapia species living in natural saline brackish water that can be cross bred with GIFT to produce lines tolerant to salinity (up to 15 ppt). Cross breeding of pure lines of Nile tilapia with species adapted to brackish water like *Oreochromis mossambicus* are also possible. The problem in Vietnam to keep the pure line broodstock is the lack of control of hatcheries which are quick profit oriented and sometimes use non improved broods. They have no good understanding of the added-value from breeding programs. Besides genetic improvement, hatchery management and transport of fingerlings should be done by professionals to reduce the actual high mortality of fingerlings. For some experts, R&D centers should aim at incremental actions (step by step) that will provide steady results: husbandry management, selective breeding on-farm (not genetic selection), teaching the basics of fry and fingerlings transportation (such a starvation period), etc.

-> There is thus an urgent need for a proper development of the broodstock/hatchery sector for Tilapia in Vietnam.

Estimated impact: Very high.

4.2.3 Grow-out

Intensification of tilapia production is a recent trend and the technology for intensive production is not developed yet in comparison with the well-developed Pangasius industry. Export-oriented tilapia production has so far been driven by ad-hoc and not well-planned initiatives from individual producers, very often in the form of a quick expansion of production with a sudden decline shortly after. This is mostly related to a lack of market information and wrong perceptions about the Tilapia market and the unique position of the Vietnamese Tilapia sector.

Production should focus on the export market quality demand first. In practise this means that export-oriented tilapia production needs to focus on The Mekong River delta areas, where Red tilapia can be produced year-round (in contrast to China, where the production season is restricted). However, the bottleneck for southern Vietnamese producers lies in the competition with China which remains the world leader on the export market with cheaper prices and has started since 2015 producing ASC certified tilapia (Villegas, 2015).

While the infrastructure for grow-out is already developed, grow-out should focus on a stable and continuous production of high quality products. Production and development of volumes need to be well coordinated in order to avoid quality loss and sudden ‘delivery’ problems. Citing Urch (2015), “it is to be hoped that the Vietnamese tilapia producers learn from the mistakes that have been made, and are still being made, with Pangasius, and continue to produce a high quality fish that can be sold at a high price so everyone will benefit, right along the chain from the farmer at one end to the consumer at the other”.

Estimated impact: very high

4.2.4 Post-harvest, processing and use of processing by-products

Whereas processing and value adding are well-developed in Vietnam, Tilapia production should first focus on supply of constant quality and quantities. Only later should the sector develop into value-adding and processing of by-products or discards. The trimmings of Tilapia can for example feed Pangasius.

-> No priority at this time.

4.2.5 Marketing

The global Tilapia market is very advanced and well-developed. With a very late entry into the market, Vietnam needs to strongly focus on the very unique position that its Tilapia sector has. The potential of the Vietnamese Tilapia sector lays in the production of red tilapia that is higher in quality than Chinese products (i.e. certified according to ASC or GlobalGAP), but more competitive in price than higher end products from competitors such as Indonesia (i.e. Riegel Springs). The key of success lies thus in very specific markets, for example the higher end tier of red tilapia in the US market. Production should focus on this market first and can only be supported if grow-out is targeting at this market.
Marketing goes together with rigorous management and coordination of the Tilapia sector in Vietnam. The sector thus needs very strong coordination and accordant marketing that promotes the unique potential of this sector, while making sure that production meets the necessary quality standards. It is crucial that the Tilapia sector does not repeat the lack of coordination observed in the Pangasius market that eventually led to a sudden and rapid decline due to image loss. If not coordinated properly while failing to understand the very unique niche within the global Tilapia market, the Vietnamese Tilapia sector risks to collapse before it has properly started.

Estimated impact: extremely high!

5 Mud crab

5.1 Current challenges and threats

Production upscaling
A brief attention was given to mud crab production. With the support of different European projects, the mud crab's life cycle has been closed and mud crab is currently bred in captivity in hatcheries. There are over 100 hatcheries producing around 500 million crablets per year. Crablets are stocked in ponds for grow-out up to about 300 to 400 g animals within 4 to 5 months of culture. Soft shell crabs are farmed in individual small cages (1 crab per cage), inspected several times in a day and harvested before the new shell becomes hard.

Lack of feed
Mud crab culture expansion should be prevented until a good commercial feed is available. Mud crabs are currently fed trash fish, by-products from slaughterhouses and wild fish. Trash fish (small fish and finally every fish caught) is caught from the wild and sold for feed mainly (pressure on fisheries).
Development of mud crab aquaculture is currently a threat to food security as its feeding diverts fisheries sources of proteins from human consumption. The so-called trash fish is traditionally used as human food (fermented fish sauce).
The sector is in a transition phase and still needs to be sustainable in the future.

Sensitivity to bacterial diseases
Mud crabs are sensitive to vibrio's. One orientation in larval stage feeding could be skipping rotifers as starter live food and use umbrella artemia. Rotifers hold the risk to bring vibrio's in the larval culture system.

5.2 Opportunities for sustainable innovations and impact

Soft shell mud crabs are highly demanded and have good prices on the markets. Innovation needs are numerous in the sector and should focus on sustainable solutions for identified constraints. There is no much information available at different levels in the chain.

6 Cross-sectorial issues and solutions

6.1 Climate change

Climate change affects drastically South East Asia and particularly the Mekong Delta. With the Mekong Delta Plan elaborated with the support of the Netherlands, a further step should be made to incorporate developments such as “Building with Nature” for Food Security, to predict the effects of climate change on salt intrusion in the delta on aquaculture (diseases, growth performances) and to adopt new strategies for aquaculture production. Further the reduction of available freshwater by human activities in the Mekong River basin is an issue of concern for food production in the region.

The aquaculture industry in the Mekong Delta is facing big problems of climate change and intense anthropogenic activities. To understand economic benefits of adaptation on production scenarios, there is a need for a holistic and integrated system approach to identify intervention needs including infrastructure needs, resilient production systems and sectorial horizontal integration of chains to create a social economic environment targeting long term sustainability in the region.

Unsustainable use of fresh water resources (i.e. Mekong River)
Most aquaculture farms are constructed along or near big rivers, notably the Mekong River, due to their dependency on fresh water. However currently China, Laos, Thailand and Cambodia plan to build various dams along the Mekong River with some construction work already completed or going on. Access to water will become a real challenge in the future. In upstream areas closer to Cambodia, fresh water availability might not be guaranteed on large scale due to conflicts of interest and may affect freshwater aquaculture production downstream in Vietnam. China's dam construction on the Upper Mekong has already caused downstream impacts affecting livelihoods of millions of people dependent on the river for food, income, transportation and a multitude of other services.

Salinization
In addition, increased seawater intrusion with salinization of large land areas further contributes to fresh water scarcity. This affects negatively food production and incomes of farmers in the area. Low yields of Pangasius and most likely of Tilapia are due to occur in provinces near the Mekong delta. The impact of climate change will be more severe to shrimp production because of its high sensitivity to changes in climatic conditions and the narrower geographical production range near the cost. Adaptation measures are needed through production of salt tolerant strains and crops.

6.2 Sustainable feed

Most fishmeal and fish oil are still imported or come from local trash fish fisheries for feed production in Vietnam. Furthermore, trash fish are fed to mud crab. Both are a threat to wild fish populations. Important farmed fish species in Vietnam namely Pangasius and Tilapia have low animal protein content requirement in their diet. Pangasius is omnivorous and Tilapia is omnivorous/planctonivorous and both can be fed alternative plant protein ingredients and other non-fish protein sources.

There are many feed producing companies in Vietnam. Feed industry produces feed for three main freshwater fish species (Pangasius, Tilapia, Snakehead) and for shrimp (small volumes). The Pangasius industry is the biggest aquafeed market in Vietnam. One feed company that has participated in the interview targets a production of 1 Million ton of feed with 95% for only the Vietnamese aquaculture market at the end of 2016. The company is working to position on the market with quality feed in the country and for expansion in the region. The company has already 7 feed factories in Vietnam with a fish feed production line and a research & demonstration facility with indoors and outdoors facilities to test different feeds, to study the nutritional value of feed ingredients, the digestibility of amino-acids, to develop an optimal nutrition, to train the farmers in good feed management practices and to showcase good results. The final target is the optimization of the feed

formulation and cost in regard to the nutritional requirement of the fish, the final product [white or yellow fillet] and with less environmental impact (more digestible feed). Quick developments of effective feeds are possible with Pangasius farmers which are more professional, collect physical parameters, keep records related to feed and growth of fish, and can discuss improvements made. The Tilapia sector is still based on small scale farmers for which there is a need to professionalize the farm management capacity.

Introduction of alternatives to fishmeal and fish oil in feed is depending on the production cost price and the knowledge on their efficiency. The company interviewed has set 3 steps in his R&D priorities: 1) focus on ingredients present on the market, 2) nutrient density and digestibility improvement and 3) trial of novel ingredients. Although it is always best to use as much of available local resource as possible to reduce costs of imported ingredients, the company invests in the search for alternative feed sources such as insects, microalgae, microbial proteins, seaweed, which have a potential in the future. Insects have potential as feed ingredients but the production is not yet fully developed nor yet scalable at local conditions. Production cost is still too high and there is no reliable sourcing. Further research is needed to improve the digestibility of insect chitin. Costs of extraction of nutrients out of algae are still too high as well. Feed ingredients in Vietnam and other developing countries should also be sourced from other value chains for example: brewery yeasts, pork wastes, etc... In opposite to breeding programs in which the government has to play a proactive role, sustainable feed development should be left to private companies in partnership with research institutes.

6.3 Coordination and spatial planning

The lack of coordination and spatial planning are a major handicap to the entire aquaculture sector. Unsustainable use of fresh water resources and a lack of area-based disease management pose a high risk to farming operations. Part of Pangasius, and in particular Tilapia (and other species) are still farmed in concentrated locations by many small holders in different places along the Mekong River. This type of spatial organization gives too much risk for disease exchanges between farms rendering implementation of biosecurity challenging. Spatial planning should allocate large spaces for Pangasius and Tilapia, special areas focusing on one production type. Better coordination and planning are needed at this level. The environmental degradation by the whole industry in the Mekong Delta is not giving the global picture of the impact. Environmental Impact Assessments (EIA) have only been carried out on a project basis. There is an urgent need for Strategic Environmental Assessments (SEA) and/or Cumulative Impact Assessments (CIA). Furthermore, a full Life Cycle Assessment (LCA) or total impact of the aquaculture industry activity on the Mekong Delta is needed.

6.4 Organisation of farmers

The government and the aquaculture producers should start thinking beyond the farm level at the district, province and national level in a more cooperative way, an all-inclusive organization of farmers adopting collectively a broad range of best management practices and enjoying better redistribution of market shares. Moving the production associated risks beyond the farm level can contribute to reduce production costs and the cost of certification while improving the market accessibility. Since Vietnamese farmers are clever and hard workers and given their mercantile profit-oriented profile, they can easily take up new innovations in farmer's organizations that show proven profits.

There are different forms of organization through which collective actions can be taken:

1) cooperatives (formal).

2) associations. Farmers are organized in associations as well (f. ex. shrimp breeder association in Soc Trang).

3) clusters (formal). Pangasius and Shrimp companies make clusters on the basis of business relationships (buying relationship).

4) landscape based organization, also called zonal/ecosystem/landscape approach, of farms that share risks.

5) the entire value chain.

At the country level, better organisation of farmers, coordination and marketing will be necessary for a long-term development of the aquaculture industry. Public private partnership (PPP) models can assist in sharing market information between large scale, medium and small scale farmers and contribute to a better organization of the sector.

6.5 Water, system and disease management

Overall and independently from the supply chain, there are needs for better strategies for water, systems and disease management. All these efforts need policy support from the government and financial support from investors. For example, in shrimp culture, systems are not well managed by small scale farmers who do not have the capacity to invest in better systems that reduce disease risks. An overall water management planning is necessary for water supply, treatment and discharge in production areas. Farmers should have water filter ponds before use and wastewater treatment ponds before drainage. Some farmers now use (semi-) recirculated systems and release water after cropping.

7 Conclusions and recommendations

Different projects and partnerships, both public and private, NGOs, from Europe, Asia and international bodies like FAO and WorldFish have in the past supported the aquaculture industry in Vietnam to develop to the actual level it has achieved. Further sustainable development of the sector depends on adoption of new approaches developed from lessons learned.

Although constraints are different per supply chain and should be tackled differently, there is a global need of strategy and long term vision at different levels in the supply chain from production to market.

Key priorities for intervention are:

- Better coordination at all levels with the involvement of all stakeholders.
- Organisation and integration of smallholders into long-term development plans.
- Sectorial and area-based management instead of narrowly focussed project work, including impact assessments, development plans, management and marketing.
- Focus on improving productivity and product quality while reducing negative social and environmental impacts.
- Better and focussed breeding programs, improved feed formulation and management, and coordinated disease management as core technical priorities.

8 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

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