PROJECT X

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Shrimp

FEED-X Value Chain Analysis

Part 1: Production System and Country Profiles

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Edited by Project X

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1st Part of two-part report

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Executive Summary

There were four key sustainability opportunities consistently found across the four shrimp value chains reviewed;

1. Input substitution
2. Sustainable transport/logistics
3. Waste water sludge use as a by-product of shrimp farming, and
4. Service development

Other areas of opportunity to improve the sustainability for shrimp value chains are;

- Traceability /certification,
- By-product use, and
- Energy/emissions reductions

The four key areas are very similar to those identified by the Salmon value chain assessment and analysis report.

Sustainability issues and opportunities relating to the value chain for shrimp feed are present across the entire value chain. However, some of the most significant issues lie upstream with respect to the sustainability of production of shrimp feed input ingredients. The findings are split into two reports; the first presents the production systems and country profiles, and the second presents the sustainability hotspot analysis results in detail.

1. Input substitution

Most notably, there are sustainability issues relating to production of fishmeal. Due to the finite resource of available wild caught fish and the difficulties inherent in monitoring vessels at sea, this is an input which has been plagued by human rights issues and illegal, unreported, and unregulated fishing. This has been most widely reported in fisheries in South East Asia, specifically Thai fisheries. However it affects a broad geography. Whilst significant progress has been made to increase sustainability of fishmeal production, namely through the use of certification schemes and the combined efforts of industry and government, these issues have still not been completely resolved.

A key factor for enabling the future growth of armed aquaculture, to keep pace with anticipated demand, is to reduce the dependency of fish-derived products in aquaculture feed products. In light of this, many feed companies have reduced the percentage of fishmeal in their feed and have replaced this with sources of vegetable derived products, such as soymeal and palm oil. This is not without its sustainability issues, which try to be addressed through certification schemes or roundtable approaches, although there are still challenges linked to traceability.

Significant research is currently underway into the potential of new input ingredients, including but not limited to the use of insect meal, micro and macro-algae. Indeed, one of the biggest drivers of sustainability in shrimp feed will come from developing a deep understanding of the sustainability issues associated with these new input ingredients, and putting appropriate safeguarding frameworks in place as these are not yet covered by ASC and other certification schemes.

2. Waste water sludge use as a by-product of shrimp farming

To maintain clean grow-out conditions for the shrimp, and thereby minimise the disease risk, the sludge needs to be removed. Filtration systems use a central drain to clear sediment and detritus material from the bottom of the pond. Farm workers operate the central drain multiple times per day to remove this waste, helping to create a clean environment. Central drains also allow farms to recirculate water.

Fertilisers derived from sludge is typically used in local agriculture, so transport distances are minimal. Applicable agricultural applications include

- Rubber plantations
- Coconut plantations
- Sugar plantations

Seaweeds are also used manage the nutrient levels of the sludge as they remove dissolved nitrogen and other organic compounds thereby improving water quality. Some seaweeds remove up to 6.5 g of ammonium nitrogen per square meter of water per day (Mata, Shuenhoff, & Santos, 2010). Nori is an edible seaweed with high economic value that farmers often grow alongside their shrimp ponds to filter the wastewater. This seaweed removes up to 93% of ammonium nitrogen from the water in intensive systems and over 50% in open-water systems (Wu, Kim, Huo, Zhang, & He, 2017). This can be a significant sustainability gain if it saves on the waste water treatment system. In Vietnam 70% of the area is used for (feed) waste treatment and has a high energy consumption of 3.5 kw/kg.

3. Sustainable transport/logistic

The analysis in three out of four of the countries explicitly mentioned transport as an area of potential for sustainability gains; some felt there was scope for more efficient transport routes from feed mill to feed customers (Ecuador). Transport of Shrimp was also being kept in ice inside insulated containers and transported by truck either to processing plants or domestic shrimp markets. Other markets were noted to be very fragmented, so that in India feed distribution cross large distances to the farms was seen as an area of negative impact. Although Vietnam did not explicitly mention transport it is highly dependent on ingredient imports (60%) and the imports of other ingredients including broodstock.

It is highly likely that feed mills in all four countries could review opportunities for making transport sustainability gains on an individual level. There is a degree of uncertainty about the sustainability opportunities in other areas of the value chain, all products and processing require refrigerated transport system to get the products to markets.

Additional areas of investigation

In this report, we have identified additional potential sustainability opportunities, some of which require further investigation. These include, amongst others, potential opportunities for increased recycling, particularly of plastic packaging at the farm level and the potential for greater reuse of waste streams. We have also identified risks that require further investigation, namely the level of environmental risk. This still exists in reduced water exchange semi-intensive systems in Ecuador, some intensive systems in Thailand and Vietnam as well as semi-intensive systems in India.

4. Service development

In all systems and geographies, a key driver of feed-related sustainability is reduction of the feed conversion ratio. This references the amount of feed (in kilograms) required to produce 1 kg of farmed animal (round weight). Due to the huge tonnage of shrimp produced each year, reducing the FCR in shrimp aquaculture systems even by a relatively small amount can have enormous associated total sustainability benefits. Therefore, all countries offer service development opportunities. Some like Ecuador, are moving to digital systems, however just improving the professionalisation of farmers, through more traditional training and extension services that enable them to improve their feed conversion ratio (FCR) potential will contribute to sustainability gains. Even in countries where the shrimp industry is still young and evolving, there is potential for consistent training and delivering a package promoting best practice.

In Ecuador, a more sophisticated system, a recent initiative by feed manufacturers is the development of digital services for farmers is enabling more accurate yield forecasting. Similarly, the focus on nutritionally optimised feeds (and services e.g. Cargill's 'SmartShield' program) promotes shrimp health, growth and survivorship, and reduces disease, positively impacting the FCR. As all of these initiatives work together to benefit FCR they therefore offer significant sustainability gains.

However, optimising the sustainability from digital tools requires shrimp farmers to have in place sufficient technical infrastructure - this is a risk to uptake and would need to be assessed in terms of specific geographies. Although all four countries have Smart phone use and SMS, its coverage in rural areas needs to be understood.

Ecuador summary

In Ecuador, the value chain for farmed shrimp has a high level of vertical integration and there is high consolidation at the farm level. Shrimp production is therefore relatively sophisticated and this results in sustainably farmed shrimp, which typically attracts premium prices. In a move to further differentiate Ecuadorian shrimp from those produced in other countries, the Ecuadorian Chamber of Agricultural Commerce has committed to obtaining ASC certification for all farmed shrimp.This will require feed manufacturers to adhere to the requirements of the upcoming ASC feed standard. Semi-intensive shrimp farms in Ecuador typically use pathogen resistant broodstock and have relatively high biosecurity, thereby minimising mortality from disease and predation. In addition, feed manufacturers produce high quality feed intended to maximise growth and survivorship of the shrimp, and there is high use of automated feeding equipment a the farm level in order to minimise overfeeding. A recent initiative by feed manufacturers is the development of digital services for farmers to enable more accurate yield forecasting. All of these initiatives work together to benefit FCR.

Indian summary

The Indian shrimp industry started to produce pacific whiteleg shrimp later than the Vietnamese, only from 2010 onwards. While the introduction started at a moderate phase, by the end of 2017 95% of the country´s production consisted of pacific whiteleg shrimp. Future expansion of shrimp farming in India is expected to be driven by new brackish water farming areas in states like Orissa, West Bengal, and Gujarat, and the expansion of farming areas in fresh water across the country. Important to note is that intensification of shrimp farming in India is limited due to a restriction on stocking densities of 60 PL/m^2.

Thailand summary

In Thailand shrimp farms are highly fragmented at the farm level. The shrimp industry is consolidated downstream, with the majority of the export market dominated by a few large companies with in-house processing. Shrimp farming in Thailand is a mature industry, with some farms going back three generations. Consequently shrimp farmers are relatively knowledgeable and rarely use banned input materials such as antibiotics. The Thai shrimp sector suffered a significant downturn in 2013 due to widespread shrimp mortality from EMS disease; this lead to closure of many shrimp farms. Many of those that survived adopted a relatively sustainable model of intensive shrimp farming known as "intensive 2.0" intended to reduce the risk of disease. This includes use of pathogen resistant broodstock and an operating methodology intended to keep grow-out condition clean and free from pathogens. As a result, the disease risk has considerably lessened. However, the outbreak of disease remains a key sustainability issue in Thailand, with intervention opportunities relating in large parts to improved biosecurity.

Vietnam summary

Shrimp production in Vietnam is almost equally split between the production of black tiger shrimp and the production of pacific white-leg shrimp. However, the vast majority of semi-intensive and intensive farmers focus production on whilteleg shrimp. The further expansion of extensive to (semi) intensive shrimp ponds and an introduction of high density super intensive farming systems has lead to increasing demand for feed. Four companies account for 80% of the total market. At the farm level though, independent farms still produce 80-85% of the shrimp production.

Next steps

The four countries chosen for this initial study were Ecuador, Thailand, Vietnam, and India. Indonesia was not chosen at this stage; despite being the largest producer of farmed shrimp, it was a market of less interest to the corporate lead. Therefore, there are some key questions to consider as part of the next steps:

- Assess whether to extend the study to Indonesia
- Validate findings with interviews across the value chain in priority countries
- Ensure that category specification is applicable to shrimp as it is for Salmon.
- Focus the Category De-Rsking studies to assess in particular:
    - Labour/human rights violation risks in more detail
    - Certification and sustainability standards applicable
    - Locally sourced ingredient inputs – nutritional value and digestibility
    - Life cycle analysis of the specific systems (attention being paid to landuse) including transport, logistics, and water quality
    - Clarify the regulatory frameworks in the EU and US that impact shrimp production (antibiotic use, antioxidants, and colourants)
    - Price volatility

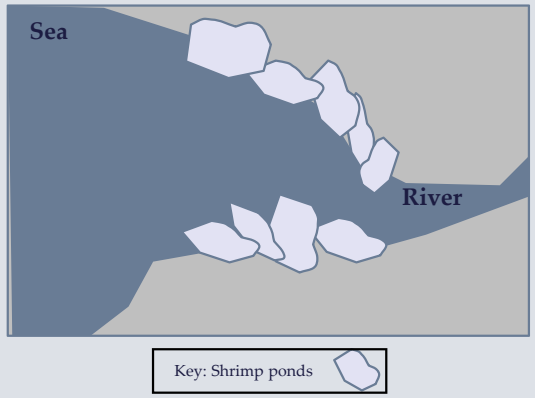
1. Shrimp production system definitions

Shrimp production system definitions:

- Extensive
- Semi-intensive
- Intensive
- Super-intensive

Extensive system

Typical set-up of extensive shrimp farms



Source: FAO 2016; Shrimp News International

Typical design[1]:

- Ponds generally irregular in shape and size
- Integrated into the natural environment
- Pond design typically includes a peripheral ditch 10–20 m wide and 30–60 cm deep
- Water exchange through pond gate – open during rising tide; closed as tide recedes

Typical parameters

Pond size	1 – 100 hectares[1]
Pond location	Typically in low-lying impoundments along bays and tidal rivers[2]; often in mangrove areas
Pond preparation	Pond renovation typically once each year
Aeration Stocking	None / very minimal
density Species	Low – typical range from 8- 14 PL/m2[3]
	Depends on geography. In Asia extensive is always with *P. monodon,* in South and Central America extensive is always with *P. vannamei*.. P. vannamei is the more predominant farmed species[2].
Yields	50-500 kg/ha/yr[1]
Use of artificial feed	Limited - Shrimp feed mainly on natural foods enhanced by fertilization; some use of low protein formulated diets[3]

Methods of operation

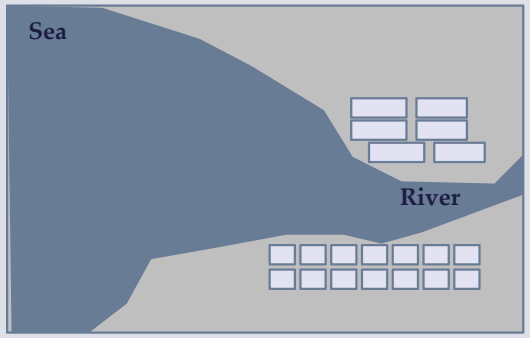
- Extensive farming is the most natural approach to shrimp farming, and is considered the simplest culture approach
- Shrimp farms are integrated into the natural environment, with low-lying impoundments along bays and rivers, including mangrove areas
- Historically, all seedstock came from the wild, and either gained entrance during water exchange or was intentionally stocked by the farmer with fry collected from the wild. Seedstock is now increasingly sourced from hatcheries to minimise the risk of disease and to enhance growth rates thorugh genetic improvements.
- The tides provide a water exchange rate of from 0 to 5% per day. Some (limited) pumped water exchange
- Use of fertiliser / manure to promote algal growth
- Some use of chemicals to control natural predators
- Polyculture systems can be common; typically they can combine a culture of shrimp and milkfish. In brackish water in Vietnam, India and Bangladesh polyculture is not common, in Indonesia in some areas it is just like in the Philippines. In fresh water, polyculture of shrimp/prawn and fish in rice fields is very common.
- Some farms are reportedly exploring organic production as a means of increasing market price. Increasingly in extensive production systems, farmers are encouraged to integrate mangrove trees in their ponds for the purpose of coastal protection at the same time as water filtering.

In most countries extensive shrimp farms use little artificial feed. Therefore, for the purpose of this work on sustainability issues and intervention opportunities in the supply chain for shrimp aquaculture feed, they have not been considered further.

Source: [1]FAO 2016; [2]Shrimp News International; [3]FAO Cultured Aquatic Species Information Programme

Semi-intensive system

Typical set-up of semi-intensive shrimp farms



Typical design[1]:

- Mix of relatively small nursery ponds and grow-out ponds in a grid pattern; larger ponds with lower shrimp density than in intensive farms
- Pumped water exchange, typically up to 25% water exchanged daily
- Flow-through system with supply canals, drain canals, and sluice gates. However, some mixing of water from neighbouring farms.

NB: as the satelite images show on page 16 the two systems are often mixed in practice.

Source: FAO 2016; Shrimp News International

Typical parameters

Pond size	1–5 ha[1]
Pond location	Non-tidal, low salinity areas. Generally above the tide line
Pond preparation	Ponds usually renovated once each year - drying of pond bottom; treatment of undrainable portions with pesticides e.g. chlorinated hydrocarbons; propagation of natural food through fertilization
Aeration	Minimal aeration
Stocking density	Medium - range from 10–30 PL/m²
Species	Farmed species include P. monodon (which is not well suited to more intensive farming practises) in addition to P. vannamei (predominant species[2]) and other species. Dependent on geography (e.g. 95% of Ecuadorian shrimp production is P. vannamei[5])
Yields	500–5,000 kg/ha/crop, with 2–3 crops per year
Use of artificial feed	Moderate, to augment natural foods

Methods of operation

Creation of artificial ponds with pumped water exchange[1;3]

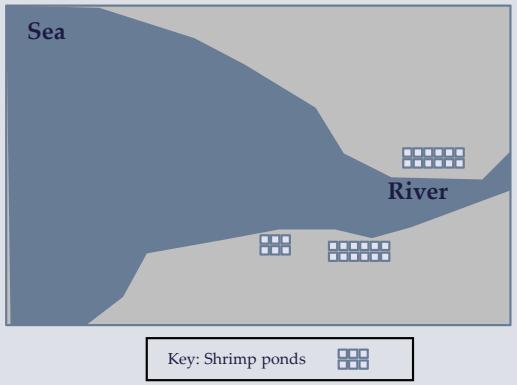
- Artificial ponds generally created above the high tide line. Therefore, pumps are required for water exchange with natural water sources
- Shrimp are stocked at higher levels than would be common in the natural habitat
- Shrimp feed on natural foods, enhanced by pond fertilisation with both organic and inorganic fertilisers
  - Fertilisers are applied to stimulate plankton blooms which in turn stimulate zooplankton. Plankton blooms also provide shade to the pond bottom and utilize the nitrogenous and phosphate wastes within the pond. The shade also helps to prevent the growth of harmful benthic algae[4]
- Further feed supplementation with artificial feed. Feeds generally placed in feeding trays and inspected a few hours later to monitor consumption. Increasing use of automated feeders
- Regular pumped water exchange, with exchange of up to 25% of the water each day
- Ponds are harvested by draining the pond through a net, or using a harvest pump
- Presence of predators such as tilapia, gobies, small crabs and tarpon is a problem. Trapping methods include cast nets, or collection by feeding trays or traps. Some use of pesticides although strict regulations exist regarding pesticide residues in shrimp.
- Ponds typically renovated 1 x each year

- **Review of semi-intensive farms in this report is focussed on shrimp farming in Ecuador, although it should be noted that there is an overlap between the two systems in practice. As such semi-intensive systems can be considered extensive by some practitioners.**

Source: [1]FAO 2016; [2]Shrimp News International; [3]FAO Cultured Aquatic Species Information Programme; [4]TNAU Agritech portal; [5]USDA GAIN report 8/21/2015

Intensive system

Typical set-up of intensive shrimp farms



Source: FAO 2016; Shrimp News International

Typical design[1]:

- Mix of relatively small nursery ponds and grow-out ponds in a grid pattern
- Each pond is connected on one side to a supply canal, typically drawing water from rivers or the sea
- Each pond is connected on the other side to a drain canal which eventually returns water to the original source
- Sluice gates control the amount and rate at which water enters and exits the ponds.

Typical parameters

Pond size	Generally small (0.1–1.0 ha)
Pond location	Non-tidal, low salinity areas
Pond preparation	Ponds completely drained, dried and prepared before each stocking
Aeration	Heavy aeration is necessary for water circulation and oxygenation
Stocking density	High - range from 60–300 PL/m²
Species	Mostly P. vannamei as it is less sensitive to non-natural conditions than P. *monodon* (95% of Thai shrimp farms raise mostly P. vannamei[2])
Yields	7–20 000 kg/ha/crop, with 2–3 crops per year (max. 30–35 000 kg/ha/crop); year round crop production in tropical climates
Use of artificial feed	Approx. 100%

Different types of intensive shrimp farms

High water exchange systems (e.g. those typical in Indonesia)

- Typically water exchange rates of >30% per day and water resources often shared
- Environmental issues
  - Environmental problems caused by untreated effluent
  - High organic load from brackish water sources settles out in grow out ponds, thus increasing the level of deterioration of the pond bottom
  - High risk of disease outbreaks

Closed and reduced water exchange systems (e.g. those typical in Thailand)

- Closed and reduced water exchange systems introduced since the outbreak of viral syndromes as a measure to reduce disease outbreaks
- Careful monitoring and management is required of feed, water quality, aeration and phytoplankton blooms . In larger farms various forms of water and effluent treatment are used, including shrimp toilets.

Bacterial floc systems (e.g. some in Belize, Indonesia)

- Ponds managed as highly aerated, recirculating, heterotrophic bacterial systems.
- Low protein feeds are used in an effort to increase the C:N ratio to >10:1 and divert added nutrients though bacterial rather than algal pathways.
- Stocking at 80–160 PL/m², the ponds become heterotrophic and flocs of bacteria are formed, which are consumed by the shrimp, reducing dependence on high protein feeds
- Reduced FCR and increased cost efficiency
- Such systems have realized productions of 8–50 000 kg/ha/crop in Belize and Indonesia.

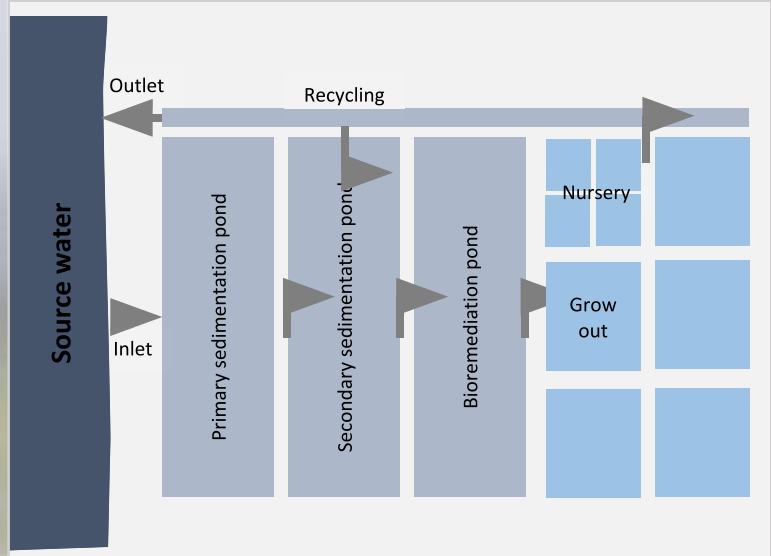
Integrated muti-trophic aquaculture (IMTA) systems (e.g. some in Mexico and China)

- High filtration capacity comes from added biodiversity from different trophic levels
- IMTA incorporates both bivalves (e.g. non-biofouling oysters) and seaweeds to maximize the recycling and conversion of both organic and inorganic compounds thereby limiting the environmental damage caused by shrimp effluent. At lower densities it can include fish (e.g. China – shrimp, clam, rabbit fish)
- Bivalves remove suspended particulate organic matter including phytoplankton, bacteria, and uneaten feed. This reduces fouling and increases oxygenation.
- Seaweeds remove dissolved nitrogen and other organic compounds thereby improving water quality. Some seaweeds remove up to 6.5 g of ammonium nitrogen per square meter of water per day (Mata, Shuenhoff, & Santos, 2010). Nori is an edible seaweed with high economic value that farmers often grow alongside their shrimp ponds to filter the wastewater. This seaweed removes up to 93% of ammonium nitrogen from the water in intensive systems and over 50% in open-water systems (Wu, Kim, Huo, Zhang, & He, 2017).
- More than one harvestable crop, and therefore higher profits, for farmers

Source: [1]FAO 2016; [1]Shrimp News International

Super-intensive system

Structure of super-intensive farms



Typical design

- Semi-closed farm with 2 phases (nursery + grow out) and high level of recycling
- Source water from canals and tributaries of rivers.
- Between 60-80% of total surface area used for water treatment.
- 5 to 6% of daily water exchange with syphoning
- Culture ponds are small, with plastic lining, reducing influence of soil type
- Outlet treatment is rare.
- Some farms produce bio-gas from sludge

Pond size	Rectangular or circular pond of 1000-3000m^2, sometimes above ground
Pond location	Can be in areas not naturally suitable for shrimp culture. Example: inland freshwater areas, areas with sandy soil.
Pond preparation	Ponds completely drained/dried after culture cycle and disinfected. Time between crops only 2-3 weeks before stocking.
Aeration	Intensive aeration at surface using paddle wheels and air injection at pond bottom.
Species produced	White leg shrimp (*Litopenaeus vannamei)*
Stocking density	200-500 ind m^{-2}
Yield	100-150 Ton ha^{-1} year^{-1} . The 2 phases cycle allows up to 4 crops per year.
Nutrient input	All nutrients from compounds feeds. Farmers also intentionally maintain biofloc which acts as a supplementary nutrient and helps maintaining water quality

Methods of operation

- Super-intensive shrimp farming is a recent farming model in Vietnam (<4 years).
- It is the result of the transition away from traditional and open shrimp culture models toward increasingly efficient and controlled intensive farming systems.
- It requires significant investment and high expertise in shrimp farming, and is therefore accessible to a limited number of farmers.
- Super-intensive systems are based on 2 main principles: Increased prophylaxis by reducing dependence on external water source to a minimum coupled with high control over inputs, pond conditions and husbandry
- Not all farm setups are the same but tend to all dedicate 60 to 80% of their surface area for recycling waste water from ponds.
- These recycling systems, often composed of multiple ponds, also include a separated pond for receiving and treating water from outside before injection into the farm system.
- Various steps compose the treatment process including liming, sedimentation, bioremediation by bacteria and algae, and application of pre-biotiocs.
- Increased control over production means stocking densities are above 200 ind m^{-2}, much higher than intensive systems stocking ~100 ind. m^{-2}, resulting in higher yields and compensating for the loss in production area.
- Despite the large water treatment areas created and the high level of intensification, there is no recirculation of water in the ponds, only water is replaced when removing sludge or practicing emergency replacements.
- Water quality in ponds is thus ensured by maintaining high quality and tightly controlled bio-flocs.
- This require careful control of pond water quality. More specifically: carbon & nitrogen ratios and composition of microbes inside the pond.
- Conversely to extensive systems, these ponds are highly photosynthesis negative and can consume up to 6 mg of oxygen per liter per hour through bacterial respiration, equivalent to 80% of the total oxygen saturation at 27 Celsius degrees.
- A significant amount of oxygenation from paddle wheels and aerators at pond bottom is therefore required to avoid development of hypoxic conditions.
- Electricity consumption often exceeds 200 HP/ha and represents up to 15% of the production cost.

Source: Fresh Studio internal survey (2018)

Shrimp production system in Ecuador above and India below; satelite images (1km scale)

Shrimp production system in Thailand above and Vietnam below; satelite images (100 meters scale)

2. Semi-intensive shrimp feed value chain in Ecuador

Semi-intensive shrimp feed value chain in Ecuador

- Country profile
- Feed suppliers in the chain

The government regulatory role in the Ecuadorian shrimp farm market, drives sustainability

- A number of Governmental bodies exert a regulatory role in the Ecuadorian shrimp farm market, thereby driving uptake of sustainability across the supply chain. These include amongst others[1]:
  - The Ministry of Industries and Productivity is responsible for the elaboration of policies geared at increasing domestic productivity and competitiveness. There have been some efforts to provide technical assistance and financing to small- to medium-size operations
  - The Vice Ministry for Aquaculture and Fisheries oversees the enforcement of non-environmental regulations, as well as administering land concessions and water use
  - The Science and Technology Secretariat funds the sector's research and development programs
  - The Institute for the Promotion of Exports and Investments (PRO ECUADOR) pursues overseas market access and promotional activities
  - The Ministry of the Environment regulates farm and laboratory operations, enforcing environmental standards.
  - The Ecuadorian Cámara Nacional de Acuacultura (CNA) sets policies relating to shrimp production in Ecuador
- In addition, FAS Quito through its co-operators promotes the use of U.S.-origin soybean meal and grains in Ecuador's shrimp feed. The U.S. Soybean Export Council provides technical assistance to shrimp farmers utilizing U.S. soybean meal[1].
- There has been a commitment by the Ecuadorian Cámara Nacional de Acuacultura (CNA) to obtain Aquaculture Stewardship Council (ASC) certification[1]
  - This enables Ecuador to position itself as a provider of premium-quality, sustainably produced shrimp
  - This positioning reflects the high level of sustainability that has been achieved across the supply chain in the Ecuadorian shrimp industry
  - It also reflects the development of full traceability, which has been enabled by the presence of relatively large farms and a high level of vertical integration
    - *"In Omarsa's processing plant each box of shrimp comes with a traceability code that links the final product with the farm that it was sourced from"*
      - Undercurrent news article 4 July 2016

Sources: [1]USDA GAIN report 8/21/2015

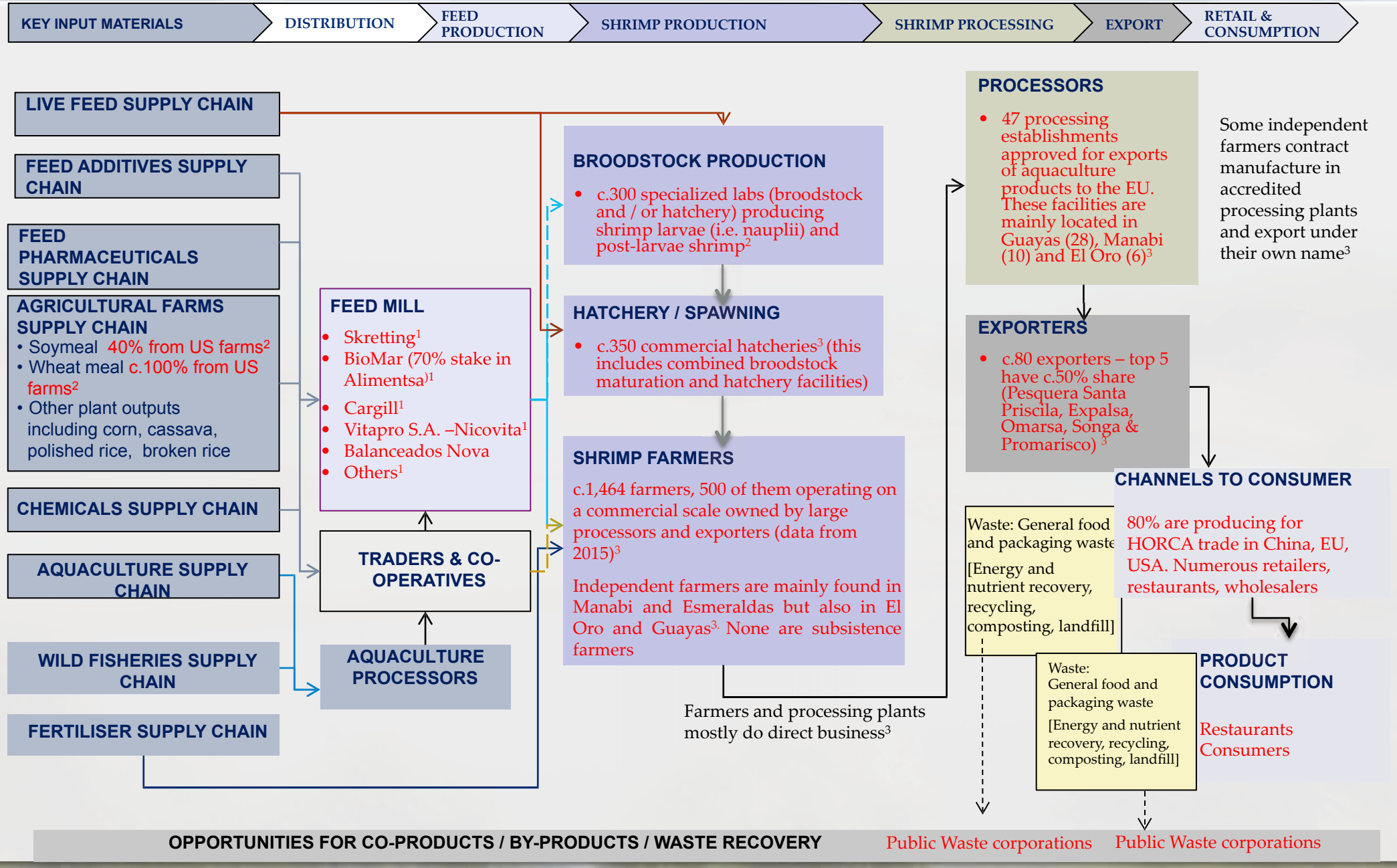
As a result of historical epidemics of shrimp disease, the Ecuadorian shrimp industry ahs invested in better farm management and high quality broodstock – the result is a high level of sustainability

- To mitigate against disease outbreaks in Ecuador, the industry uses specific pathogen resistant (SPR) broodstock[1]
  - There is little use of antibiotics, as this is not necessary due to the rearing of SPR post-larvae and good farm management practises and the pond size. Antibiotics may still be used to counter other pathogens where there is no resistance. In practice, antibiotic use in hatcheries is not always transparent.
- As viral diseases are not typically expressed at the nauplii stage[3], it is very important that postlarvae are reared to PL-12 in well managed hatcheries
  - the Ecuadorian shrimp industry has invested in the establishment of some 300 specialized laboratories producing shrimp larvae (i.e., nauplii) and post- larvae shrimp[4].
- Semi-intensive shrimp farms in Ecuador are typically built on an incline. This enables seawater to be pumped into the site, then ponds to be drained using a floodgate system[2].
- In many countries, semi-intensive farms operate daily water exchange rates of up to 25% each day. In contrast in Ecuador, most farms operate reduced water exchange systems[3]
  - This minimises potential introduction of harmful pathogens with the incoming water, thereby reducing the risk of disease outbreaks
  - It also reduces pumping costs and associated energy use and GHG emissions
  - It has lessened the environmental impact associated with release of nutrient-rich effluent into the sea
- Reduced water exchange systems are made possible in Ecuador in particular by use of balanced feeds which are created to meet the nutritional requirements of the shrimp whilst minimising negative impacts on the environment
  - This minimises the level of nutrient enrichment from faeces and uneaten feeds
- These systems are also made possible by farmers taking care not to over-feed shrimp with formulated feeds and supplements
  - High levels of vertical integration and the presence of large farms enables feed suppliers to deliver technical advice to farmers to optimise feeding regimens. This also minimises the volume of waste materials and build up of sludge
  - There is high use of automatic feeding equipment, designed to deliver formulated feeds only when the shrimp are actively feeding
- Feed manufacturers also offer advice to farmers around biosecurity in order to minimise levels of predation
  - Advice on biosecurity enables farmers to maximises the potential yield. There is no use of pesticides.
- In addition, farms in Ecuador prefer relatively low stocking densities as this positively impacts shrimp survivorship, however this may change as it moves towards increasing investments in energy infrastructure which would enable farms to invest in paddlewheels.

> *"After lowering densities recently, prices rose and shrimp survival rates went up to about 75% to 80%, from 55% typically. With more biomass from less density, I doubt if Ecuador will [increase densities]."*
>
> Jose Antonio Camposano, head of Ecuador's National Aquaculture Chamber, as reported in Undercurrent news article 4 July 2016

Sources: [1]Cargill Sustainability Report 2017; [2]Undercurrent news article 4 July 2016; [3]Interview with Benchmark Plc; [4]FAO 2015

Shrimp Aquaculture Supply Chain – Semi-Intensive Farming (Ecuador): Core Firms and Stakeholders



Sources:
[1]Undercurrent news article Oct. 19, 2017;
[2]USDA GAIN report 8/21/2015;
[3]Seafood trade intelligence portal

Most shrimp feed producers in Ecuador are aware of their environmental footprint regarding the production process and are taking steps to address it

- An ASC standard[6] covering shrimp feed production is due to be released later in 2020
- There has been a commitment by the Ecuadorian Cámara Nacional de Acuacultura to obtain ASC certification for shrimp produced in Ecuador[1]
- Many large feed manufacturers in Ecuador are therefore gearing up to meet the upcoming ASC standards relating to the feed production process
  - Most feed companies have been gathering data about process related sustainabilities, and have been setting sustainability targets. Many now monitor their environmental footprint.
  - Opportunities for sustainability improvements will be bespoke to the specific production processes and the equipment in place in each facility
  - Not all feed manufacturers in Ecuador release information about their process efficiency targets, so it is possible that some do not have these policies or targets in place. This is a blankspot.
- It is noteworthy that shrimp production in Ecuador has been increasing , and therefore shrimp feed producers have responded by opening new production facilities and expanding and upgrading existing facilities[7]. As a result, many facilities in Ecuador therefore include state-of-the-art feed production machinery and processes[7]
  - e.g, Cargill's new plant (2018)at Guayaquil; Skretting's fourth plant in Ecuador (2018); recent $30m investment in Nicovita's plant in Ecuador to triple production capacity

Stated process related sustainability targets of the leading shrimp feed producers in Ecuador (note that process sustainabilities generally refer to total aquaculture feed production and processing)

	Water	Energy and GHG emissions	Use of byproducts	Recycling
Cargill[1]	Initiatives to reduce water use in some facilities will be started in 2020	Targeting 20% reduction in GHG emissions by 2020. Year on year energy savings through efficiencies in production and investments in equipment	Byproducts comprise c.30% of the tonnage of raw materials used to make feeds. No information is provided on targets	c.70% of waste currently recycled – aim is greater recycling, particularly of plastic waste
Biomar[2]	Targeting 10% reduction per kg feed by 2020	Targeting 20% reduction per kg feed by 2020. Recent investments in new feed production technology to enable new product techniques.	Biomar states that it endeavours, as far as possible, to utilize by-product raw materials in feed production	Target 100% reuse, recycling, and recovery of generated waste by 2020
Nicovita[3]	No specific sustainability information has been released although Nicovita's website states that the company is "Focused on the sustainability of the aquaculture industry"			
Skretting[4]	Little sustainability information has been released, although Skretting's 2017 global sustainability report states that "100% of Skretting feed factories monitor their environmental footprint. We have implemented data collection, recording and analysis systems in our factories." Skretting Chile started a project to reduce water consumption achieving reduction in water consumption per tonne of feed from 1.42 m3 down to 0.74 m3.			
Balanceados Nova[5]	During the compilation of data for this report, we did not find any published information for Balanceados Nova relating to feed production-related sustainability initiatives or targets			

Feed company focus on the upcoming ASC feed standard would be expected to drive further sustainability benefits associated with the feed production process in Ecuador

Sources: [1]Cargill aqua nutrition sustainability report 2017 ; [2]Biomar Group integrated sustainability report, 2017 ; [3]Nicovita website; [4]Skretting global sustainability report 2017; [5]Balanceados Nova website; [6]ASC website; [7]Undercurrent news article Oct. 19, 2017

Steps taken to address upstream sustainability issues include sourcing from certified suppliers and research into potential new inputs

- Feed producers in Ecuador are increasingly sourcing from certified suppliers, as exemplified by Cargill and Biomar. Data is not available for all feed manufacturers, and it is possible therefore that not all of them have sustainable sourcing policies in place. Evidence of sustainable sourcing is expected to be required in order to meet upcoming ASC feed standard however this requires verification once the new standard is released.
- Transport sustainabilities from input manufacturer to the feedmill are also important.

Cargill [1] -	upstream sustainability focus
Fish-based inputs	• Cargill sources from 120 fisheries of which 29 are Marine Stewardship Council (MSC) certified and 24 are working towards MSC certification • Target is to source all marine ingredients from IFFO RS certified factories by 2020, and by 2025 to only source MSC certified marine ingredients
Plant-based inputs	• To address deforestation concerns, by 2020, source all soy products from supply chains that meet FEFAC benchmarked certifications. By 2020, only source palm oil products audited to RSPO or equivalent
Supplier code of conduct	• In 2017, all of Cargill's suppliers (>700) provided evidence that they adhere to the same principles with respect to key aspects of environmental and social impacts and responsibilities of their business.
R&D capability	• Cargill Innovation Center (CIC) in Colaco, Chile, opened in 2017 – initially focussed on health diets for salmon, this now also includes R&D on shrimp diets
Emerging inputs	• This is covered in more detail in a separate report produced for Project X[3]. Current / existing trials include amongst others novel EPA/DHA inputs such as algal oils and GM canola, trials on insect meal, and Calysta's FeedKind protein material from fermented methane gas.

Biomar [2] -	upstream sustainability focus
Fish-based inputs	89% of fish meal and 81% of fish oil is sourced from fisheries certified to IFFO RS or equivalent 100% of krill meal is sourced from suppliers meeting MSC standards
Plant-based inputs	BioMar buys exclusively deforestation-free soybean and palm products 82% of soybean is purchased from suppliers certified by RTRS, ProTerra or equivalent 100% of palm oil is purchased from suppliers certified by RSPO, Green Palm or equivalent
Supplier code of conduct	Biomar suppliers are required to adhere to its Code of Conduct. This covers areas such as human rights, health & safety and environmental care.
R&D capability	Biomar dedicates 1% of gross revenue to R&D, in addition to actively seeking out research grants. In November 2017, BioMar announced plans to invest in a new shrimp research centre in Ecuador.
Emerging inputs	This is covered in more detail in a separate report produced for Project X[3].

Sources: [1]Cargill aqua nutrition sustainability report 2017 ; [2]Biomar Group integrated sustainability report, 2017; [3]PWC market opportunity report June 2018

Cargill and Biomar (amongst others) are gearing up to meet the upcoming ASC feed standard, and are investing in R&D into potential new inputs in pursuit of competitive edge and to sustain growth

3. Intensive shrimp feed value chain in Thailand

Intensive shrimp feed value chain in Thailand:

- Country profile
- Feed suppliers in the chain

Historical siting of some farms in mangrove areas has led to reduced biodiversity – these are reverting to more natural methods of shrimp farming

- Historic siting of some Thai shrimp farms in mangrove areas has removed important areas of mangrove, leading to reduced biodiversity
  - *"Mangrove loss negatively impacts a key ecosystem for carbon storage, adds to emissions of planet-warming carbon dioxide, and exposes shorelines and communities to storm surges and erosion"*[1]

- In an effort to restore mangrove habitat, the IUCN has been working with Thai shrimp farmers sited in mangrove areas to encou rage a shift from intensive farming to more natural farming
  - *"A shift from intensive farming to more natural farming is more sustainable in the long run,"*
    - Supranee Kampongsun, mangroves and markets project coordinator for the IUCN[1]

- In addition, the Thai Government has implemented a mixed land-use policy to allow communities in certain areas to use degraded mangroves for income on the condition that half the area is maintained as mangroves or converted back to them[1]

- There is little surplus land remaining in Thailand by which to grow the shrimp farming industry, therefore many shrimp farmers are against the shift from intensive farming to more natural farming in mangrove areas[4]

- Reversion to more natural methods of shrimp farming in mangrove areas opens up the opportunity for production of organic shrimp
  - 95% of intensive Thai shrimp farms currently farm whiteleg shrimp (*P.vannamei*)[2], however uptake of organic farming practises would be expected to increase production of black tiger shrimp (*P.monodon*) which thrive in natural conditions
  - Thai Union is currently looking at production of black tiger shrimp to ASIC standards. This is a move to organic farming with integrated mangroves[3]

- Organic farming with integrated mangroves typically involves low stocking densities relative to intensive farming, and consequently there is negligible (if any) requirement for manufactured feed
  - Stocking density of 2-5 shrimp per m2[1]

- The extent of organic farming in Thailand appears to be very limited, and industry experts[4; 5] have indicated that this is not expected to be a major impact factor in regard to intensive farming in Thailand – we therefore do not anticipate a material impact on the required feed volume

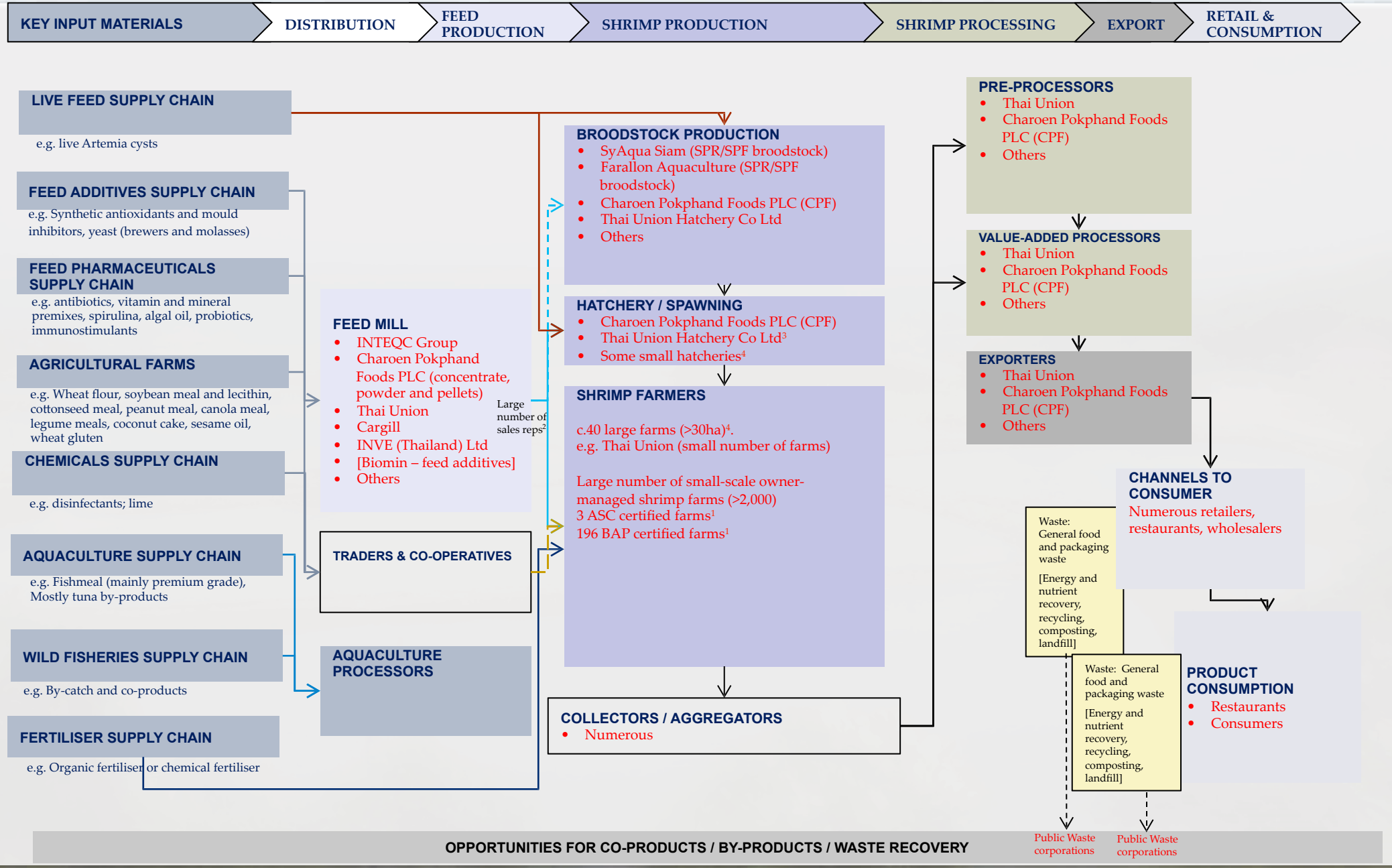
Sources: [1]Thomson Reuters Foundation article February 1 2016; [2]Shrimp news international; [3]Thai Union interview; [4]Rubicon Resources interview; [5]Benchmark interview

Regional farmer cooperatives could prove a useful network through which to drive the uptake of sustainability initiatives in Thailand

- A powerful potential driving force of sustainability initiatives in Thailand are the strong regional farmer cooperatives that exist in key shrimp production areas
  - Regional co-operatives provide a meeting place for farmers, enabling them to share ideas, and exchange information, whilst also providing a focal point for dissemination of information
  - They also deliver a degree of self and / or mutual monitoring of sustainable farming[1]
- Following the widespread crop failure in 2013 due to outbreak of Early Mortality Syndrome (EMS), farmer cooperatives were essential in spreading information about best practise strategies for disease management, thereby enabling surviving farms to recover and adopt new more sustainable farming methods (such as Intensive 2.0)
- Feed manufacturers can leverage local cooperatives to drive sustainability initiatives at the farm level
  - For example, in 2017, the Trang Aquaculture Cooperative signed a memorandum of understanding with government and CP Foods to promote large-scale white shrimp farming sustainably. The aim is to transfer techniques under CPF's "3 Clean" principles, to small shrimp farmers in the Trang province, in effort to sustainably tackle shrimp diseases, reduce the cost of production, and boost output of high quality, contamination-free products[2].
- Groups of small shrimp farmers are sometimes organised into cluster groups, which facilitates sustainability initiatives at the group level
  - For example, the 'Good luck' shrimp exporter sources shrimp from farm clusters, and participants in each cluster can apply for group- level BAP aquaculture certifications[3]

Sources:[1]FAO technical paper; [2]Undercurrent news article May 5 2017

Shrimp Aquaculture Supply Chain –Intensive Farming (Thailand): Core Firms and Stakeholders



Sources: [1]Seafood Trade Intelligence Portal; [2]CP Foods website; [3]Thai Union website; [4]CSR Asia case study

In Thailand published sustainability targets is driving sustainability

- Some Thai feed producers, including Thai Union, have signed up to the Thailand Voluntary Emission Trading Scheme (Thailand V-ETS). This brings together the private and public sector to monitor, report and verify GHG emissions in Thailand.
- Incentivising processors to sign up to schemes such as the Thailand V-ETS establishes environmental targets as a tool for combatting climate change
- Opportunities for sustainability improvements will be bespoke to the specific production processes and the equipment in place in each facility

Stated process related sustainability targets (where given) of the leading shrimp feed producers in Thailand (note that process sustainabilities generally refer to total aquaculture feed production and may include processing)

	Water	Energy and GHG emissions	Use of byproducts	Recycling
INTEQC Group	During the compilation of data for this report, we did not find any published information for INTEQC Group relating to feed production-related sustainability initiatives or targets			
Charoen Pokphand Foods PLC	Target to reduce water withdrawal per production unit by 25% by 2020 compared to the base year 2015 (23.38% reduction already achieved by 2017)[1]	Target reduction of energy consumption and GHG emissions by 15% per production unit compared to the base year 2015 (11.6% reduction in energy consumption and 6.97% GHG emissions already achieved by 2017)[1] Current use of biofuel (husk, corn cobs, palm, firewood)[1]	In Thailand, only use fishmeal derived from byproducts e.g. tuna byproducts[1]	Target to reduce waste disposal to landfill and incineration by 30% compared to the base year 2015 (9.08% reduction already achieved by 2017)[1]
Thai Union	Target 20% reduction in water use per production unit by 2020[2]	Target 30 percent GHG reduction by 2020[2]	All fish-derived by-products currently come from TU tuna processing plants; pass on their byproducts to other industries[2].	*"Thai Union puts effort into segregating, reusing and recycling our waste to reduce the volume that goes to the landfill"*[2]
Cargill	Initiatives to reduce water use in some facilities will be started in 2018[3]	Targeting 20% reduction in GHG emissions by 2020[3]. Year on year energy savings through efficiencies in production and investments in equipment[3]	Byproducts comprise c.30% of the tonnage of raw materials used to make feeds. No information is provided on targets[3]	c.70% of waste currently recycled – aim is greater recycling, particularly of plastic waste[3]
INVE	During the compilation of data for this report, we did not find any published information for INVE relating to feed production-related sustainability initiatives or targets			

Sources: [1]CP Foods Press Release 21/07/2017; [2]Thai Union 2017 Sustainability Report; [3]Cargill aqua nutrition sustainability report 2017

4. Intensive shrimp feed value chain in Vietnam

Intensive shrimp feed value chain in Vietnam:

- Country profile
- Feed suppliers in the chain

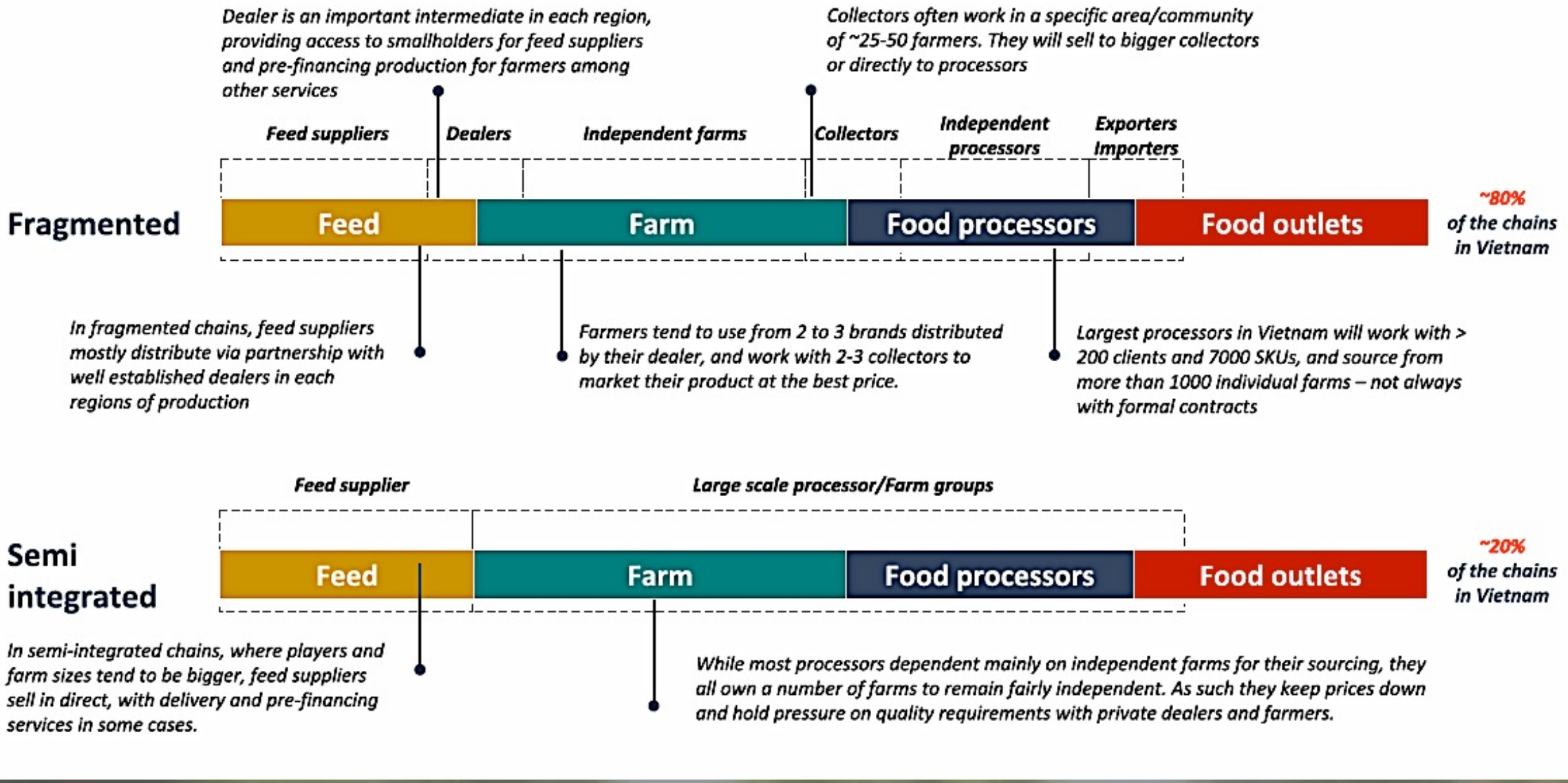
Vietnam country profile

	Quality	Price Competitivity	Diversification
Reliance	52% seafood export revenue from shrimp in 2017		
Size	-683 000 tonnes in 2017 (62% Pacific whiteleg shrimp. 37% Black tiger shrimp) -83% from the Mekong Delta		
Market	-80% for export, USD 3.8 billion USD in 2017 -Top 10 countries make 90% of total value - EU holds largest market share (22%)		
Products	-65% HS 0306, 35% HS1605		
Governance	Regulations at farm level set by the Ministry of Agriculture and Rural Development (MARD) and are implemented under the Department of Fisheries and veterinary department.		
Processing	485 factories in the Mekong Delta, Central Vietnam and North Vietnam process and/or trade cultured shrimp.		
Farming	- Dominated by small scale independent farmers - 85% of non-traditional farmers grow Pacific White-leg shrimp - Some White-leg production comes from rice –shrimp systems, but most comes from intensive and super intensive farms		

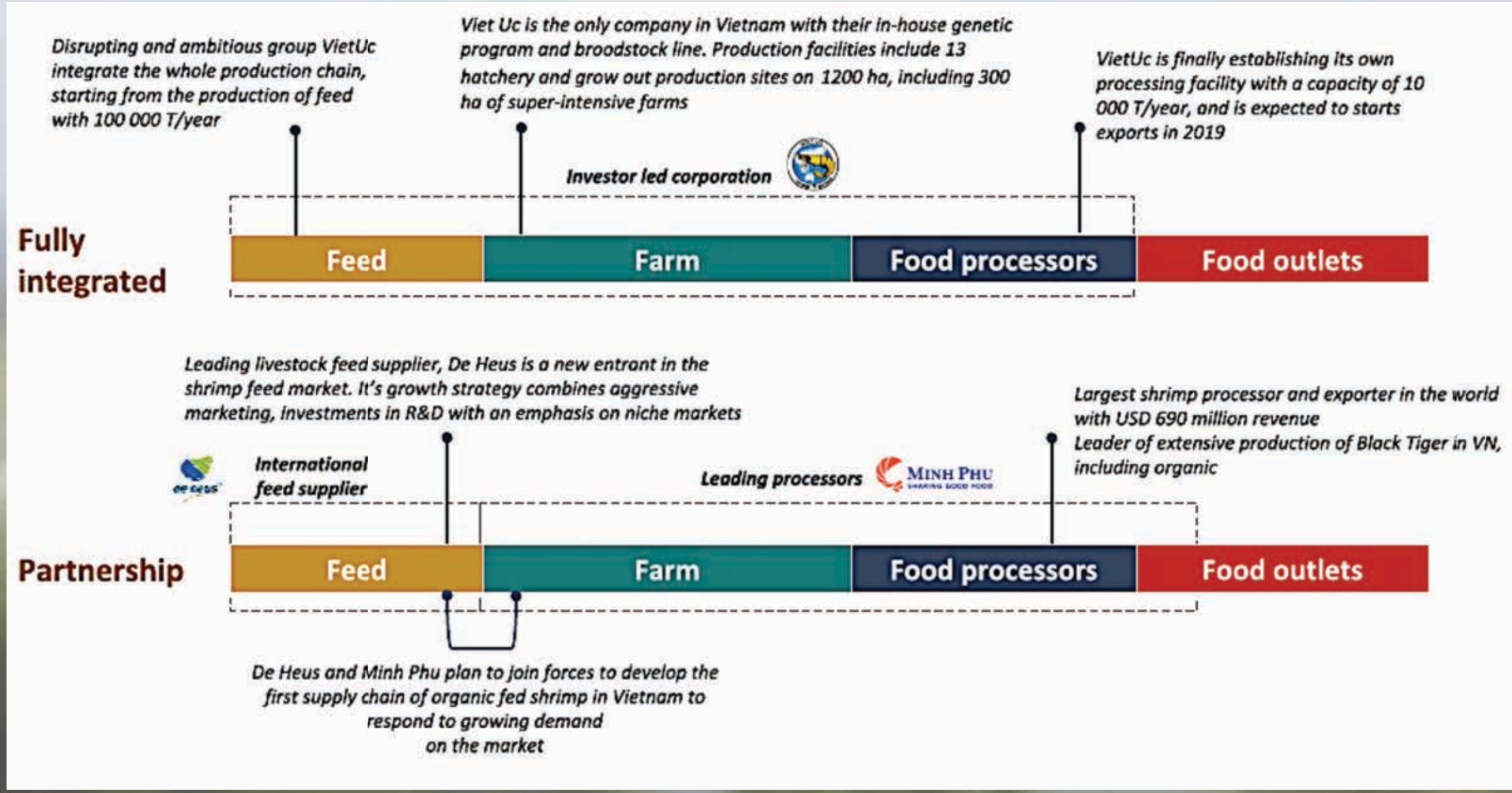
	Quality	Price Competitivity	Role in the Chain
Rank	3rd world producer of aquafeed		
Volume	Total pacific white-leg shrimp feed market size in 2017 is + 600,000 tonnes (Total Aquafeed production in 2017 is around 3.1 million tonnes according to Alltech feed survey 2018)		
Companies	25 companies Circa. 50 factories		
Market structuration	- Top 5 companies hold 86% market share - 4 foreign companies (Skretting, Cargill, Grobest and Tong Wei) or their local subsidiaries hold 80% of the market - Only one local supplier (6% market share) in the Top 5 - Starter feeds are mainly produced locally		
Balance	- Local Pacific White-leg shrimp feed market is + 600,000 tonnes - Imports of feed not required by producers		
Role of feed suppliers in the chain	- Feed manufacturers are driving innovation in the supply chain with investments in hatcheries, research and demonstration centres and outreach activities - Feed companies are sometimes pre-financing production cycles and provide support to farmers.		

Source:Alltech Aquaculture Feed Survey (2018) SCAP (2014), Tep Bac (2018), VOV.VN (2018)

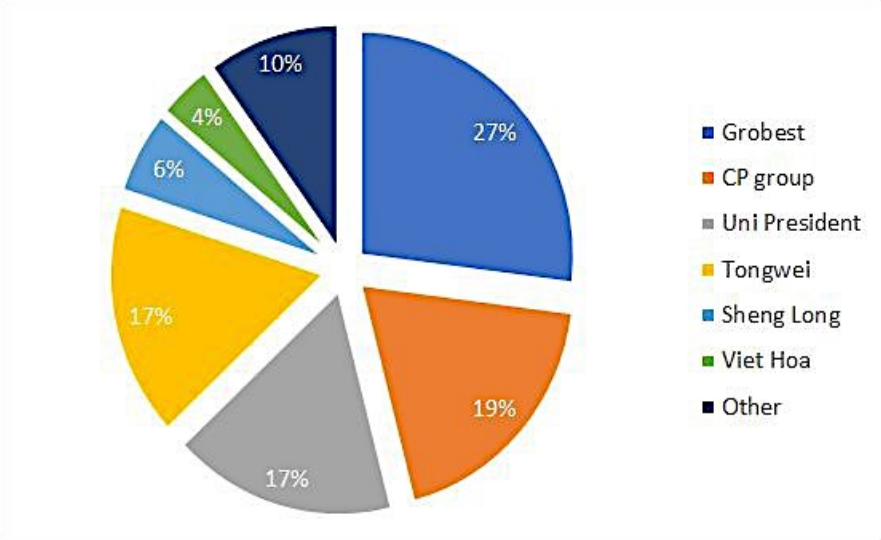
Feed suppliers in the Chain - 3 F models for traditional setups in Vietnam



Feed suppliers in the Chain - 3 F models for non- traditional setups in Vietnam



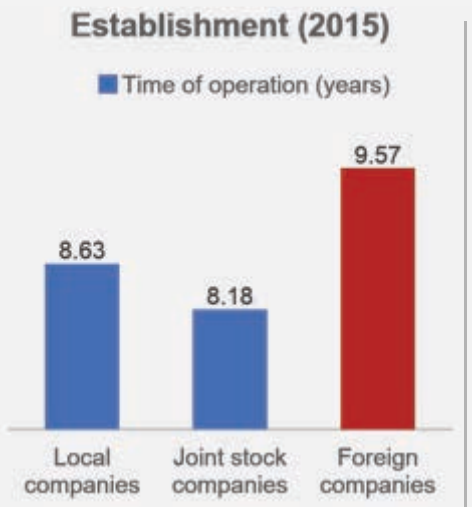
Who are the Feed players in Vietnam?



Approximately 25 companies produce shrimp feed on a regular basis in Vietnam. There are different types of players active on the market amount which we find global players (e.g. Cargill-Ewos, Skretting, In-Vivo), regional players (e.g. Grobest, CP, Uni President, and Tongwei) as well as local small scale players.

After 2000, the rapid shift from traditional extensive farming to intensive farming resulted in growing demand for shrimp feed. Resulting in the establishment of many shrimp feed companies during this period.

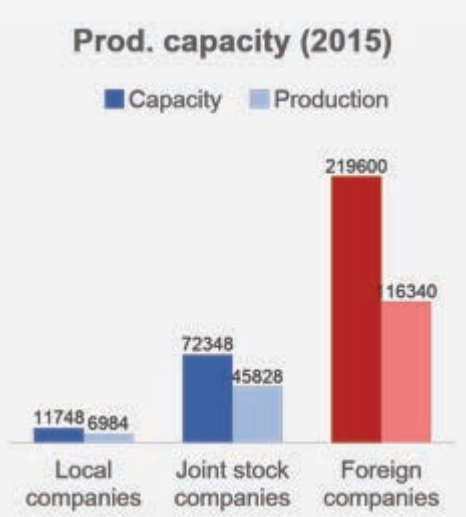
To date, 4 large (foreign) feed suppliers currently hold nearly 80% of the market in Vietnam, while 15-20 other feed suppliers fight for the remaining 20% of the market share.



C.P, Grobest and Uni President were among the first companies to establish shrimp feed production in Vietnam (1999, 2001, and 2001), often well before local companies.

Their involvement combined with their stronger financial capacity, experience and modern production line permitted them to outcompete local firms rapidly.

Despite being accursed of monopolisation, it has also helped Vietnam to develop a modern White-Leg shrimp culture sector, driving costs down, fostering improvements through R&D and developing modern distribution systems



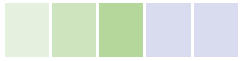
Dominant producers have now entered in a firm competition. As a results, most feed plants above 50,000 tonne capacity belong to foreign companies, with ambitious plans to increase production to respond to future demand for feed.

These large players are enlarging their growth strategies beyond feed productions, to provide support for farmers on disease mitigation and farming technology.

In stark contrast, any of the small scale)local) feed producers with capacity of less than 10,00 tonnes/yr are either shutting down or are reducing production

Source: Bocquillet (2014), Alltech Aquaculture feed Survey (2016), Aquaculture Asia Pacific (2017), SCAP (2014)

Extreem Market Representation: David vs. Goliath

	Charoen Pokphand (CP)			Dai Phat		
	Access to finance	R&D Capacity	Involvement in the chain	Access to finance	R&D Capacity	Involvement in the chain
						
Countries	20			1		
Market entry	1993: livestock, 1999: shrimp			2009: livestock, 2015: shrimp		
Production	3 facilities ~610 000 T/year capacity (total aquafeed)			1 facility		
Other Structures	PL production: 7 hatcheries, 14 million/year, 15% market share Processing: USD 66 million value/year, 1/3 shrimp			~ 150,000T/year (total aquafeed) None		
Certifications	ISO 9001, ISO 14001, ISO 22000, ISO 50001, GMP, HACCP, GLOBAL GAP, BAP.			HACCP, ISO 22000:3005		

Notes	• One of the first agri-corporations in shrimp to include extension services for independent farmers.
	• Extension services include provision of seed, technical services, and purchase at final harvest.
	• In the early 2000's was one of the first companies to introduce and develop WL shrimp farming in Thailand. Research at their breeding facility propelled the establishment of white leg production in Thailand.
	  • Drove development of disease free post larvae
	  • Improved growth rates and survival of genetic strains
	• Their technology and skills continue to be exported to other Southeast Asian countries. Strong marketing has driven the dissemination of new production techniques. Including the '3 cleans approach' or the 'CP farming model'.
				• Relatively new entrant into the market and focusing on production and sales.
				• Has established 200 distribution centers across Vietnam
				• Also invested into product development by establishing an R&D lab to improve feed formulation.
				• No notable activities in extension, seed production or processing.		

Source: CP Sustainability Report (2'017), The Fish Site (2011), Dai Phat (2016), SCAP (2014)

Shrimp Aquaculture Supply Chain – Intensive Farming (Vietnam): Core firms and stakeholders

KEY INPUT MATERIALS → FEED PRODUCTION → DISTRIBUTION → SHRIMP PRODUCTION → SHRIMP PROCESSING → EXPORT → RETAIL & CONSUMPTION

Brood stock supply chain
- 97% of WL brood stock from USA, Thailand, Singapore
- Shrimp Improvement Systems, CP Co, Kona Bay Marine resources

Feed ingredient supply chain
- Approximately 60% of ingredients imported
- Orizon S.A., Fiordo Austral, Pacific Star, Alimentos Marinos, La Portada, Hayduk, Camanchaca, Pelagia, Triple9 (Global), CASES, Navico (Local)
- Domestic production only rice flour, cassava flour and low quality fishmeal.

Chemical & feed additives
- Additive, probiotic and veterinary treatments ingredients supplied by wholesalers in Europe & USA
- Bayer, Virbac, Evonik, Aquativ, INVE
- But prevalence of products with unclear origin.

Feed Mill
- 4 companies make up ~80% of total market share.
- All are major players are foreign based companies or joint ventures
  - Grobest (27%)
  - CP (19%)
  - Uni-President (17%)
  - Tongwei (17%)
  - Viet Hoa (4%)
  - Thanh Long (6%)
- Some feed suppliers also integrate hatcheries and processing

Dealers & Distributors
- Will trade inputs with farmers and other distributors within an area.
- Farmers will often source inputs from dealers nearby due to frequency of purchase, convenience.
- Dealers often bind farmers by selling inputs on credit.

Hatcheries
- Estimated 350 whileleg hatcheries
- Viet Uc, CP, Nam Mien Trung, Thong Thuan, Chau Phi, Thanh Long, Nam My
- National demand: 70 billion PL (whiteleg)

Shrimp farmers
- Approximately 11,000 whiteleg farms nationwide
- Average 10-15% of supply from corporate owned farms. 80-85% from independent farms
- 227 shrimp cooperatives and producer groups registered, but average membership is only 20 members.
- Hoa Nghia, Toan Thang, Hoa Phat, Thuan Thanh, Hoa De, Thuan Thanh
- Therefore, only a margin of producers is integrated into a cooperative of producer group.

Collectors & Dealers
- Play a key role in linking farmers with processors who cannot manage the vast number of farmers who supply for them.
- Collectors and dealers are integrated within farming communities and frequently interact with farmers.
- The transaction process with farmers can be complex due to negotiations on weight, product quality, value.

Processors
- 485 export companies in 2017, with an average turnover of USD 7.8 million per year.
- Despite being some of the largest seafood processing companies in the world, distribution of market share is very diverse.
- Minh Phu, largest shrimp company in the world with sales of 695 million USD in 2017, holds 16% of export market share.
- Top 10 exporters in 2017: Minh Phu Ca Mau & Hau Giang (16%), CASES (3.4%), Quoc Viet (2.5%), STAPIMEX (4.9%), Fimex (3.7%), Trang Khanh (3.2%), Vilcom (2.5%), SEANAMICO (3.9%), Minh Phat (2.4%).

Source: VASP Industry report (2018), Tep Bac (2018), Nha Nong (2018), P.T. Lam (2014, STIP supplier database

5. Semi-Intensive shrimp feed value chain in India

Semi-Intensive shrimp feed value chain in India:

- Country profile
- Feed suppliers in the chain

India country profile

	Quality	Price competitivity	Role in the chain
Reliance	45% of seafood export revenue from shrimp in 2017		
Size	-600,000 tonnes in 2017 (550.000 Pacific whiteleg shrimp, 50.000 Black tiger shrimp) 66% produced in Andhra Pradesh.		
Market	90% for export, USD 4,9 in 2017 Top 10 countries make 90% of total value Most important market is the US (44 %)		
Products	- 95% HS0306, 5% HS1605		
Governance	Regulations at farm level set by the Coastal Aquaculture Authority (CAA) which falls under the Ministry of Animal Husbandry		
Processing	We estimate that over 200 factories along the east and west coast process cultured shrimp.		
Farming	- Dominated by small scale independent farmers - 100% of non-traditional farmers grow Pacific whiteleg shrimp - Mainly (semi-) intensive production systems		

	Quality	Price competitivity	Role in the chain
Rank			
Volume	Total pacific whiteleg shrimp feed market size in 2017: +- 1.350.000 tonnes (Total aquafeed production around 1.8 mil tonnes According to Alltech feed survey 2018)		
Companies	~20 companies ~35 factories		
Market structuration	- Thai Union's and CP's subsidiaries hold 80% of the market - Avanti feeds alone has 5 production units with a capacity of 600,000 tonnes and actual production in FY'17-'18 of 450,000 - 3 out of the top 5 of largest shrimp exporters have feedmills - Starter feeds are mainly imported		
Balance	- Local pacific whiteleg shrimp feed market is 1.000.000 tonnes - Local capacity is catching up and substituting imports - No or only limited exports into other markets		
Role of feed Suppliers in the chain	- Feed manufacturers are often active across the supply chain - Feed manufacturers play key role in technical support to farmers (small scale as well) - Integrated feed manufacturers often pre-finance feed to distributors and/or farmers in exchange for buy-back		

Source:Alltech Aquaculture Feed Survey (2018) SCAP (2014), Tep Bac (2018), VOV.VN (2018)

Feed suppliers in the Chain - 3 F models for traditional setups in India

Independent dealers are an important intermediate in each region but their role is becoming less significant. In many cases the role of dealers is taken by processors who use the feed distribution to get preferential buy back agreements. They need this in order to be able to secure raw shrimp for their processing.

Fragmented

Feed suppliers | *Dealers* | *Independent farms* | *Collectors* | *Independent processors* | *Exporters Importers*

Feed | Farm | Food processors | Food outlets

~60% of the chains in India

In fragmented chains, feed suppliers mostly distribute via partnership with well established dealers. In India, dealers are mostly either agents who also buy raw shrimp to supply to processors, or processors themselves. Both will sell either cash or on credit.

Farmers who are financially independent tend to buy feed and other inputs from dealers in cash instead of engaging in buy back agreements. If they don't buy on credit they tend to get better rates for feed and other inputs, and they can sell to the highest bidder when harvesting the shrimp.

Semi integrated

Feed supplier | *Large scale processor/Farm groups*

Feed | Farm | Food processors | Food outlets

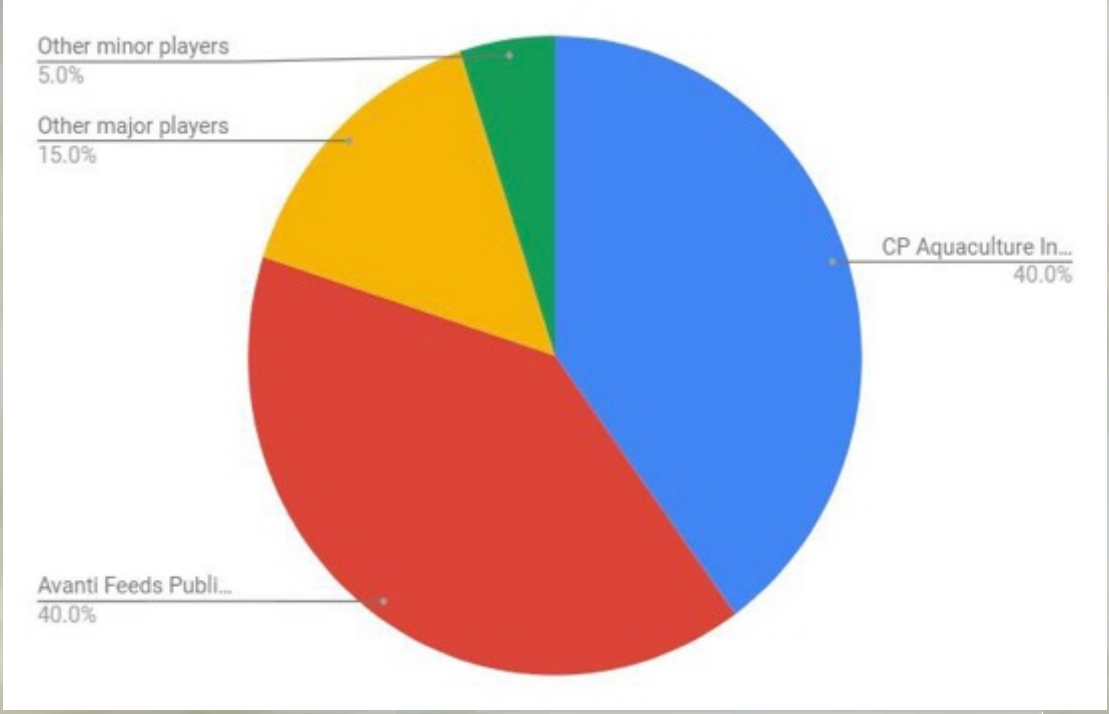
~40% of the chains

In semi-integrated and integrated chains bigger and smaller farmers buy drectly from the feed company. The feed company is in this case often vertically integrated and uses the feed business to get access to raw shrimp, or the other way around.

Bigger farms engage in partnerships in echange for good rates for the feed they buy. Smaller farms get feed and other inputs on credit and the feed supplier gets the first option when the farmer is ready to sell its shrimp. However, normally there are no contracts behind these agreements. Relationships are sometimes build on trust but often on financial dependency.

In India, there are not many alternative set ups. However, one initiative from the government, through MPEDA, is to promote the set-up of small feed mills by local SME's who use a feed formulation which results in a cheap but high quality feed for small scale farmers. Another thing reported is that a company like BMR Industries is introducing also a budget feed line with which it wants to compete with bigger feed players

Who are the feed players in India?



In India, there are about 20 companies that produce shrimp feed on a regular basis. The two dominant players in the market are CP Aquaculture India, a 100% subsidiary of CP Foods Thailand, and Avanti Food, in which Thai Union has a significant share. Both companies have quite a different strategy.

The group of “major feed players” in the graph consists of BMR, Devi, Growell, Falcon, and the Waterbase. Most of these companies are among India’s major shrimp processing and export companies. They have invested in shrimp feed manufacturing in order to be able to provide farmers with feed and PL (often pre-financed). In exchange, they will require farmers to sell back the raw shrimp in a highly competitive raw shrimp market, securing raw shrimp is crucial for the processors.

The group of “minor feed players” comprises a mix of local and global feed players and companies who are importing feed from other countries and distribute it in India. They often partner with local processors who do not have feed production but who do want to distribute feed to farmers for the same reason as above.

Important is that Indian starter feeds are not yet produced at a significant scale. Starter feeds are imported from other countries in the region like Thailand and Vietnam.

Shrimp feed production in India could for a while not keep up with the rapid expansion of shrimp farming due to the introduction of Pacific Whiteleg shrimp. However, in the past couple of years major investments in feed mills have been made. Both by existing players such as Avanti Feeds and CP Aquaculture, but also by new players such as Falcon Marine, BMR Industries, and Devi Fisheries. Competition among feed players is fierce as current capacity with all the new feed mills is far above current market demand. However, feed players are positive that with the expectation that the production of shrimp will continue to increase, the current capacity will fit future demand.

Distribution models and strategies differ. While companies like Avanti, and BMR industries, which are fully integrated, distribute a considerable share of their shrimp feed to farmers with whom they engage in buy back agreements, other players, like CP Aquaculture India, is merely a distributor. The sole reason for a company like Falcon Marine, India’s biggest shrimp exporter, to invest in feed is to be able to build a strong network amongst farmers and to secure access to the raw shrimp for processing.

The distribution of shrimp feed mills across India is unequally divided with most feed mills located in Andhra Pradesh and Tamil Nadu. However, as shrimp farming expands in states like Gujarat, West Bengal, and Orissa, shrimp feed mills are also built. In Gujarat for example, although until recently Avanti was one of the few companies with a local feed mill, but in 2018 both CP Aquaculture India and Skretting (in a joint venture with West Coast Group) announced they would open local feed mills in the locations. Where local demand is higher than production capacity, most of the feed players work with distributors (often processors) to sell and distribute their feed to the farmers.

Shrimp Aquaculture Supply Chain – Semi-Intensive Farming (India): Core firms and stakeholders

KEY INPUT MATERIALS → DISTRIBUTION → FEED PRODUCTION → SHRIMP PRODUCTION → SHRIMP PROCESSING → EXPORT → RETAIL & CONSUMPTION

Live feed supply chain
INVE
East Coast Marine Products

Broodstock quarantine center
CAA operated in Neelankarai

Broodstock supply chain

- 100% of WL brood stock from 7 companies registered by CAA
- Oceanic Institute, Kona Bay Marine Resources, Shrimp Improvement Systems, Global Blue Technologies
- Two governmental institutes to develop broodstock breeding. (Ravigandhi, CIBA)
- One company in the process of setting up broodstock breeding (BMR)

Feed Mill

- Avanti Feeds40%
- CP India 40%

Joint share of 15%

- BMR
- Falcon
- Devi
- Waterbase
- Growel

Remaining share of 5%
Grobest, Cargill, Sharat, Uni President, Godrej Agrove. Nexus, Sonac, Lion, CP Prima, RNK, Sharat, Fedora

Hatcheries

- The total PL production in India is approximately 24Bln.
- 260 hatcheries are approved to produce Pacific whiteleg shrimp and import broodstocks
- BMR and CP India are the biggest hatchery players.
- Feeds provided by Zeigler Feeds, INVE, Biomar and Nutreco

Nursery Phase

- BMR
- Other large hatchery players moving into the development of nursery phase

Agents

- There are countless agents, normally located close to the farming areas. Processors use the agents as a service provider. Agents mostly work with more than one processor but do have long term relationships. Agents are often also input distributors to farmers and have a financing role for the farming community, securing raw shrimp supply to their operations.
- The main task of the agent is to coordinate harvesting between the many small-scale farmers and the processing establishments. Factories provide farmers with high quality inputs and in many cases send their own trucks with ice to the farmers at harvest time.

Feed ingredient supply chain

- Prestige (soy)
- Vippy (soy)
- 150.000 tonnes fishmeal production installed
- Arbee-aquatic (Fishmeal)
- Mukka Sea Foods Industries Pvt Ltd (fishmeal/ fishoil)
- Bluelinefoods (fishmeal/ fishoil)

Dealers & Distributors
There are countless dealers and distributors of inputs. Sometimes these are part of exporting companies and sometimes these are independent.

Shrimp farmers
In India by law there is a limitation in the stocking density in shrimp ponds set at 60 per m2. Although some farmers tend to go slightly higher, this is a limitation of further intensification and thereby the majority of farms fit under the semi-intensive definition.

- More than 100,000 farms nationwide averaging 0.2 to 0.5 ha culture area per pond.
- Only 900 farms and clusters of farms with a total farm area of 9,000 ha are legally registered with the Coastal Aquaculture Authority (CAA).
- Only about 750 larger scale farms, but number is growing

Chemical & feed additives supply chain

- Additive, probiotic and veterinary treatments ingredients supplied by wholesalers from EU, US and Asia

Processors

- 450 processing companies in 2017
- Around 200 involved in shrimp processing.
- Top 10 exporters have approximately 20-30% market share. Top exporters include Falcon, Liberty, Devi Marine, Devi Fisheries, Nekkanti, BMR, Avanti and APEX.
- With expanding shrimp production, processing capacity also expands.

6. Innovations

Innovations:

- Innovations along the supply chain
- Innovation examples
  - Bio Bullet – sustainable solution to mussel bio-fouling
  - Additives, Novel ingredients, and Antioxidants

Shrimp related innovations associated with the supply chain

KEY INPUT MATERIALS → DISTRIBUTION → FEED PRODUCTION → SHRIMP PRODUCTION → SHRIMP PROCESSING → EXPORT → RETAIL & CONSUMPTION

Fishmeal alternatives:
Objective: to find alternative protein sources with a similar nutritional profile than that of fishmeal

Bacterial based:
- Calysta
- NOVACQ

Insect based:
- Entobel
- Protix
- Agriprotein
- Entomo farm

Plant based:
- SYLfeed
- Parabelcc

Fish oil alternatives:
Objective: to find alternative oil sources with a similar nutritional profile than that of fish oil

Algae based:
- ALIGA
- Cellana
- Many more

Insect based:
- Entofood
- Enterra

Plant based:
- NuSeed

Functional ingredients:
Objective: to develop ingredients which support the overall health and resistance of the shrimp:

Nutritional based:
- Altech
- Biomin
- Diamond V
- BASF
- Nutriad
- Diana Aqua
- Jefo
- Zeifler
- Molofeed

Pro-Biotic based:
- INVE
- Neovia
- Vinnbio
- Bioz Technologies

Health
- ViAqua
- Pharmaq
- MicroSymbiotiX
- Pockit

Distribution and farmer support
Objective: to help farmers in their daily job as an entrepreneur both on technical as on knowledge side

- Aquaconnect
- Shrimpvet
- IFB/Aqashop

Water Quality management:
Objective: to increase the efficiency of the pond, and thereby increase the efficiency of the feed used.

Jala
- Farmext
- Apps from several feed companies (Cargill, Skretting etc,)
- Osmobot

- Bio Bullet

Feeding management:
Objective: to optimize feeding management on farms

- E-Fishery
- GrowYi

Preserving shrimp:
Objective: to develop new and natural chemicals to preserve shrimp after harvesting or during processing

- Green solutions
- Xyrex

Traceability and quality assurance:
Objective: to ensure product traceability
- Verifik8
- Fishcoin
- This fish
- OpenSC

Overview of the innovation companies are some examples, in some areas there are many more, especially for the raw material alternatives.

Innovation examples: Bio Bullets a sustainable solution to Mussel bio-fouling

Innovation examples: Biofouling mussels increase shrimp mortality, lead to lower pigmentation and a lower market value of surviving shrimp - Bio Bullets provides a sustainable solution

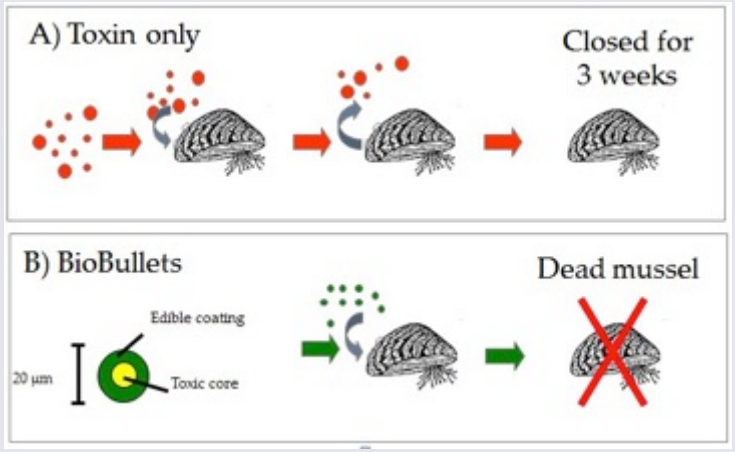
The fouling effect of unwanted mussels is an increasing problem in shrimp production, which manifests at the farm level

Image 1: Invasive mussels on the bed of a Colombian shrimp farm, following pond drain down

Image 2: Invasive mussels fouling paddle wheels

- Mussel fouling in shrimp ponds directly increases shrimp mortality and lowers their pignmentation, most notably[1]:
- mussels can close around antennae and legs, trapping them on the pond bottom,
- and leading to mortality.
- To avoid mussels , the shrimp sit higher in the water column, and results in a higher quantity of uneaten feed left on the pond floor.
- The mussel filtration increases water clarity, which thus makes shrimps more vulnerable to predation. In response, shrimps reduce their body pigmentation to reduce detection, which lowers their market value.

BioBullets – a sustainable solution



Research indicates that biofouling mussels reduces production (c.10% production loss in study sites) and increases the FCR[2]

The problem:

- In the presence of toxins, mussels will keep their valves closed for up to 3 weeks. Farm owners need to dose significant quantities of biocide for long time periods to kill biofouling mussels
- Some farm owners (e.g. previous farms in Colombia[1]) dose copper sulphate on top of the mussels following pond drain down which can affect human health and the environment

A sustainable solution:

- BioBullets' products offer a sustainable solution to the problem of mussel biofouling in shrimp ponds
- The product works by encapsulating active, tailored ingredients in particles which the mussels then eat, thereby enabling targeted product delivery.
- Products are engineered to ensure optimal buoyancy in the water column and are manufactured to food-grade standards.
- We estimate that encapsulation of the active facilitates use of 1000x less product than freely dosing. Encapsulation also facilitates use of environmentally friendly actives.

The business holds patents across a global footprint and has received numerous accolades, including the winning of the UK Research Councils' business plan competition and the Entec Medal for environmental innovation.

Sources: [1] BioBullets research; *Note filtering volume is species dependent – species such as *Mytilopsis* filter up to 2 litres of water per day compared with approx. 10 litres per day for *Perna* . Sources: [2] BioBullets research; *Production and FCR of *L.vannamei* within ponds containing *M.trautwineana* (infested) or no mussels (uninfested).

Innovation examples: Additives, Novel Ingredients, and Antioxidants

NOVACQ

- NOVACQ is a shrimp feed additive replacing fish meal and fish oil with cultured marine microbes.
- Developers claim the ingredient not only relieves dependence upon fishmeal and fish oil, but also improves the survival and growth of shrimp stock.
- Australian research group CSIRO has been developing the ingredient since the early 2000's, and announced the success of feed trials in 2013. Since then it has been collaborating with Viet-Uc on production and distribution of NOVACQ in Vietnam, revealing plans to construct a production facility for the novel ingredient.
- Australian feed producer Ridley, is conducting commercial trials in Thailand and obtained distribution rights to Vietnam just last year.

Entobel

- Entobel is a Belgian start-up based in Vietnam developing an insect meal (H-meal) from black soldier fly larvae.
- The organization established a pilot facility in 2013 which produces 90 tons/year, but plans to develop a new facility with a 4,000 ton/year capacity. The organization will need a 9 million dollar investment.
- However, lack of the regulations and approval needed to produce and trade the ingredient has been a constraint. However, acceptance of insect meal is gaining momentum, as it was recently approved for salmon in the USA and poultry in the Canada.
- According to the Entobel's CEO, Vietnam's reliance on protein ingredients coupled with its development objectives was the right environment to establish.

Green Solution

- Green solution is a Vietnamese start-up which has developed an avocado derived antioxidant preservative that can be used to prevent black spots on harvested shrimp.
- The development of black spots, otherwise known as melanosis, is often treated by sodium metabisulfite, which is associated with food safety concerns.
- Green solutions claims their product performed better than sodium metabisulfite by effect and by cost.
- During the recently held Aquaculture Innovation Challenge, the group made a proposal for $10,000 to validate their product, and an additional $80,000 to begin production on a commercial scale.

7: Next Steps

We recommend that you read the 2nd part of the report that focuses on identifying the sustainability hot spots and cool spots in the supply chains of the four countries.

The aim of this report was to identify the context in the shrimp production system and market so the sustainability issues and intervention opportunities in the shrimp feed value chain can be explored in the four different countries:

- Semi-intensive shrimp farms in Ecuador and India
- Intensive shrimp farms in Thailand and Vietnam

For consistency of approach between the Salmon and Shrimp studies undertaken by Project X as part of the problem definition stage of Feed-X, the output of this research references terminology developed in a prior report titled "Cambridge Value chain Analysis and Adaptability for Feed-X". This includes the following terms and definitions:

- Hot spots: Location of strongly negative environmental and/or social impacts
- Cold spots: Locations of strongly positive potential interventions
- Blank spots: information gaps that pose potential risks

Report Inputs

The report was informed by the PwC report, an extensive review of published and grey literature, and by referencing to in house data owned by Biobullets Ltd and Seafood Trade Intelligence Portal. This was supplemented by practical experience, primary research including interviews with the following companies;

- Benchmark/INVE (2 interviews)
- Calysta (1 interview carried out by Project X)
- Fairagora (1 interview)
- Rubicon Resources (1 interview)
- Skretting (3 interviews carried out by Project X) reviewed the interview transcripts and
- Thai Union (2 interviews)

The 2nd report builds on the understanding of the country context established here. The summary results highlighted in the executive summary combine the findings of both reports which have been split to make them more focused. The following slide provides the contents page of the assessment report.

Table of Contents for the second report

Supported by:

This document has been peer reviewed for accuracy and quality of content by at least three independent experts from credible organisations including research universities, WWF and business.

Although the utmost care has been taken to identify and correct all typographical errors, some may still exist and if found write to info@projectxglobal.com. UK spelling is used in most cases.

End

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