THE
AQUACULTURE ROUNDTABLESERIES® 2018

A shared vision for aquaculture in Asia

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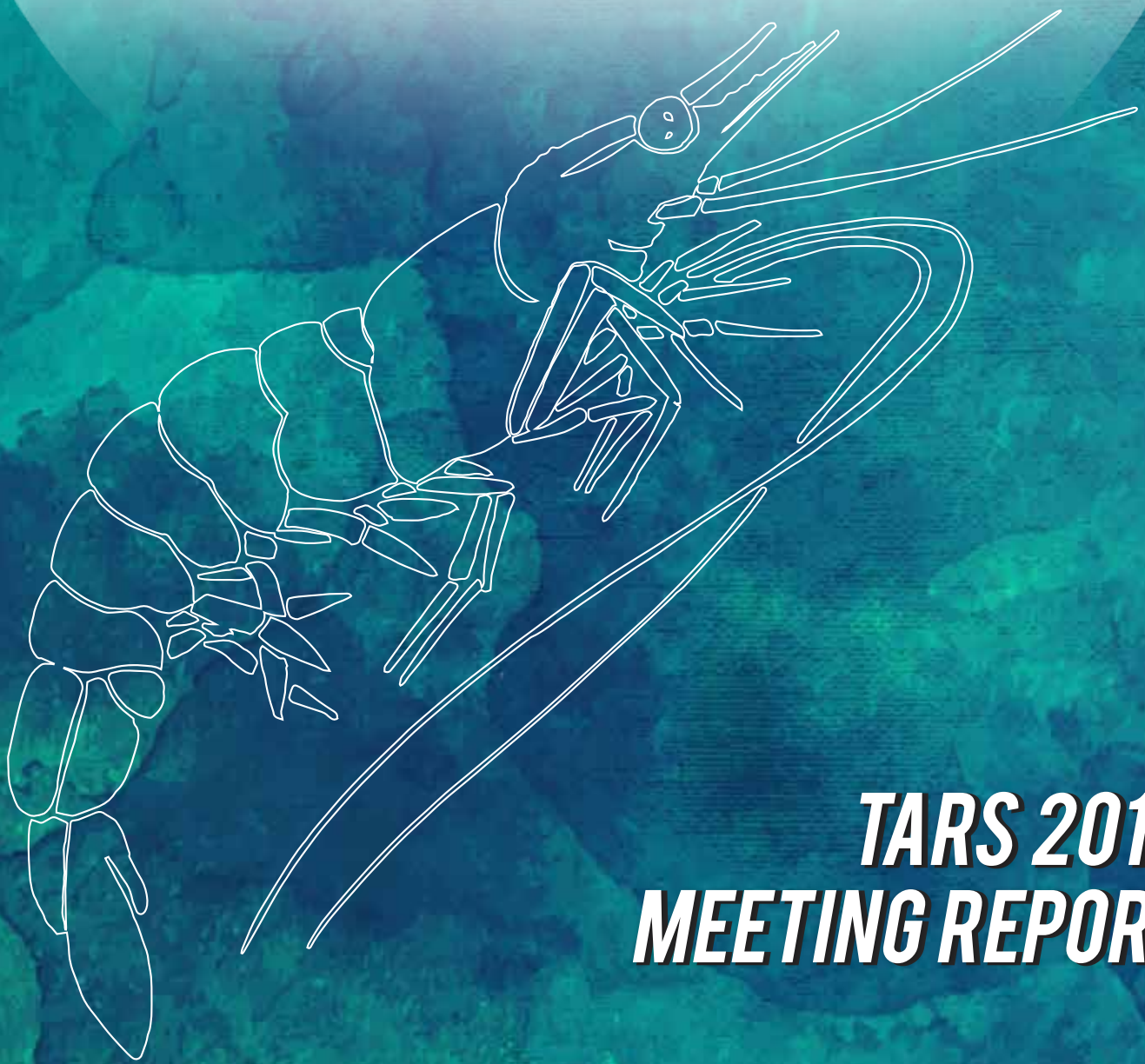
SHRIMP AQUACULTURE:
NEED FOR CHANGE



TARS 2018 MEETING REPORT

TARS 2018: Shrimp Aquaculture – Need for change

TARS 2018 was the eighth in The Aquaculture Roundtable Series; and for the fourth time, the focus was on the shrimp aquaculture industry in Asia. There was a wow factor with almost 250 participants at this gathering of industry stakeholders in Chiang Mai, Thailand from 15-16 August 2018.

In 2016, the focus was on how to take the industry to a new normal with the realisation that disease-free farming was passé. Moving forward, TARS 2018 highlighted the ***Need for Change*** and called on the industry to look at increasing efficiency and a higher level of control in production.

The plenary at TARS 2018 had five sessions, covering;

- state of industry and challenges;
- nutritional and health interventions;
- investing for the future.
- productivity in the supply chain;
- revival of the black tiger shrimp, and

During the interactive breakout roundtable session, participants deliberated on issues and priority areas for improvement and changes in genetics, hatchery and nursery; culture technology and innovation; and feeds, health and environment.

As commercial shrimp farming in Asia has surpassed almost 40 years, it is time to pass the baton to the next generation. This year's hard talk with farmers featured three second-generation farmers taking over the business from their parents. TARS 2018 was organised by Aqua Culture Asia Pacific and Corporate Media Services, Singapore and was supported by the Department of Fisheries, Thailand. Participation came from 29 countries; the largest groups came from Thailand, India and Ecuador. Industry sponsors were Inve Aquaculture, Biomin, Nutriad, Diamond V, BASF, BioMar, DSM, Diana Aqua and Jefo.

In his welcome address, **Bunchong Chumnongsittathum**, Deputy Director General, Department of Fisheries, Thailand (DOF), said, "Shrimp contributes THB 60 billion or almost USD 2 billion to Thailand's economy. It is also important as shrimp farming holds communities together. Although our current shrimp production may be less than half of our best of 640,000 tonnes in 2010, the efficiency of our sustainable culture system gives us a high level of production per area."

Post EMS, Thai farmers have adopted strategies and steps to improve survival rates to boost production but at a pace suited to themselves and their farm conditions. "The Department is responsible not only for regulating and monitoring shrimp quality but also provides support to the industry with technical services to farmers and all related sectors."

Khun Bunchong also introduced a panellist at the Hard Talk with Young Shrimp Farmers, Somthida Pakdeepak, a graduate of Kasetsart University. "She is an example of the succession planning aided by DOF and academia. At our universities, we take into consideration the trial and error experience from the first generation of farmers, and convert this into science for this next generation of farmers."

SESSION 1: STATE OF INDUSTRY AND CHALLENGES

State of shrimp aquaculture in Asia: Thriving (or surviving) in a changing world

For the second time, **Robins McIntosh**, Executive Vice President of Charoen Pokphand Foods (CPF), Thailand used his vast industry knowledge as well as his global outlook to present the state of the industry (SOI) address. At TARS 2016, McIntosh had already called for change, change and more change. In 2016, shrimp prices were at their highest and despite challenging times with diseases, the industry was in expansion mode. Today, the scenario has changed as prices began to drop when supply outstripped demand. This year, McIntosh described the new situation with shrimp markets and industry as well as proposed steps for change. .

In the supply and demand balance, high prices up to January 2018 had incentivised and supported the development of new ponds and farming areas, particularly in India and Indonesia. On the other side, there was the application of new technologies in existing farms to improve farm efficiency. "It is this combination which resulted in a rapid gain in global shrimp production over the past 2 years. But the global average in shrimp costs of production has increased. There is polarisation between farmers who have focussed on efficiency improvement and those on development of new areas.

"Today, we have a growth phase, due to the expansion of farming in new areas. This 'false rise' in supply may slow down or even reverse slightly. With production highs in India, in early January 2018, prices came down. Prices were lower, but will it put farms out of business?"

Evolution and markets

McIntosh said that in response to shrimp market economics, the trend has been for more intensification. "Today, we could have 60% of world shrimp reared through intensive systems. Hyper intensive is the next level but today it comprises only 2% of shrimp production. The message is: nothing stays the same. We will evolve and create change when we have issues in the industry, diseases and reduction in profit margins. All these will be incentives for change and rapid evolution."

Global shrimp producers target the same markets, mainly Europe, Japan and the USA. "More recently, China. If I look at the different markets and look for growth, it is in the USA and China. What are the limits to shrimp consumption? In terms of buying power, we can see real income increasing in the USA at 2%

annually, but the actual imports, assuming this is all consumed, indicate that Americans are under-consuming relative to their incomes today."

The large increases in production in Ecuador and India have been channelled mainly to China. "This surge in shrimp imports into China was attributed to its low production because of EMS/AHPND (early mortality syndrome/acute hepatopancreatic necrosis disease). Prior to that, in 2009, China only imported 5,000 tonnes of shrimp and exported 400,000 tonnes and it was self-sufficient," said McIntosh.

McIntosh added, "EMS/AHPND reduced production to probably 600,000-700,000 tonnes which have been replaced by imports. In terms of real income gains in China, it has increased by 5.5% annually. China can afford to import more shrimp." There is, however, a what if. "Will the surge in imports last? If it is able to resume production, say another 300,000 tonnes, China will require fewer imports. In contrast, the USA and Europe do not farm shrimp."

Local markets

McIntosh proposed two strategies to "beat" the export market price. "Local markets do not depend on export markets. In Thailand and Brazil, local prices are better than the export prices.

Furthermore, a strategy going forward is not just depending on selling raw commodity or products into local markets that everybody is selling into. We should look at branding and value added where we can make more money than just selling raw products as the final product."

Efficiency in production

World shrimp production has increased but clearly, EMS/AHPND, *Enterocytozoon hepatopenaei* (EHP) and white spot syndrome virus (WSSV), are still prevalent everywhere. The increase is due to some farmers who have been more efficient in handling these diseases and the opening up of more farms and ponds. "Higher global prices always stimulate new investment activities, new farms, farm improvements, and new ponds especially in India and Indonesia. But the question is efficiency."

"In 2014, with low survival rates as well as body weights and PL efficiency, the direct cost was USD 13.90/kg. On learning to manage EMS/AHPND, in 2017, we basically achieved lower production, but shrimp size was larger at a lower production cost (USD 3.25/kg)."

His message was by changing and concentrating on efficiency, profits can be increased. However, cost reductions should be considered when there are no measurable benefits or risks.

Profitability in Thailand

There is curiosity on whether Thailand has recovered. McIntosh clearly stated, "Farmers have recovered and exceeded profitability compared to before EMS. They now have a more efficient industry. This is the correct way to expand instead of building more ponds and more farms. However, we need to also look at reducing unnecessary cost. For instance, industry uses a lot of costly disinfectants, but the benefits are not measurable. Chlorine is costly, but it has never saved any pond from EMS."

Along the supply chain, the industry in Thailand is making evolutionary changes; striving again for efficiency under the new conditions. "Hatcheries have responded with more efficiency, and then the farms change for more efficient models, under the current characteristics and even processing technology is changing."

Intensive and sustainable models

"The industry will evolve towards intensification, producing more from less. Less land more shrimp, less water more shrimp, less feed more shrimp, less energy more shrimp; that will be the evolution. It will happen faster in some places than others."

As the industry moves towards an intensive sustainable model, McIntosh noted, "Many people in the industry have lost contact with the economics: profit, sales price and cost. In the 1990s, attention was on market price and not on controlling cost. Today, we should aim to be as efficient as we can, have control over production costs and the market will take care of itself." However, he said that farm gate price is created within a country relative to its economy, and world price is created by the world's supply and demand situations. In some countries, there are two supply chains. For example, in Malaysia, farm gate prices are higher than world prices because of lower domestic supply. Indian producers have the lowest farm gate prices as compared to even Vietnam and Thailand.

There are successful models in every country. The evolution is small ponds producing more shrimp at much lower costs, more water exchange in a recycle system, high aeration, reduction of pond depth, stabilisation of pond temperature, use of fish in settling ponds, use of ground water, natural filtration, liners, nurseries, and formulation of diets for fast growth.

Last words

Large versus small sizes

"When we talk to retailers like Walmart, the usual belief is that it is cheaper to grow small shrimp. Thus, I did an analysis of the cost per day to grow shrimp of different sizes. The result was that it is more expensive to grow the smaller sized shrimp and we are paid less. However, I can get better profit margins by growing big 30 to 40g shrimp as compared to 16g shrimp," said McIntosh.

"With the genetics we have now, we can grow shrimp to bigger sizes and many farms are growing 30, 40, 50 and even 60g shrimp. On costs, more farms can now produce at under USD 3.50/kg.

This will continue to play a major role in creating more efficiency. CP's fast growth shrimp reached 20 in 60 days while CP's AHPND tolerant strain will take 85 days. These are results from trials in raceways with stocking density at 150 PL/m^2. "In time, the aim is fast growing shrimp that can tolerate diseases."

Shrimp farming in India: Fast & furious – controls and caution to growth

India, one of the largest producers of farmed shrimp has been shaking the shrimp markets since early 2018. S. Santhana Krishnan, CEO, Marine Technologies and Founder President, Society of Aquaculture Professionals (SAP) discussed the pressing issues and challenges in India in his presentation on, "Shrimp Farming in India: Fast & Furious – Controls and Caution to Growth."

In 2016/2017, India produced 566,000 tonnes of shrimp and the projection for 2017/2018 was 697,000 tonnes. In 2018/2019, an increase of 13.5% in production is expected.

"Since 2014, shrimp farming expanded exponentially in India. We had large increases in farming areas and large investments. There are many new players: feed millers, farmers, hatcheries, input suppliers, etc. India became the focus of big buyers in large emerging markets. This growth propelled more investments and new entrants into the industry in 2017. Some states such as Andhra Pradesh, Gujarat, Orissa and West Bengal have very promising areas for growth," said Santhana. "Investments

in shrimp processing help the industry cope with the huge production of vannamei shrimp."

Markets and perceptions

"It is the wish list of our farmers to sell large size shrimp for large profits, which is often difficult," said Santhana, "Usually, in March to May, most of the harvested shrimp are less than 14g. From June to December, most of the shrimp are in the 20-25g range; and then from October to December, sizes are mixed: small, medium and large."

Santhana countered the latest perception among buyers that India produces small size shrimp. "No, we do not deliberately produce small sizes. Because of the rampant disease outbreaks, we get mixed sizes which coincide with the seasons of the year. Every Indian shrimp farmer wants to produce large shrimp but due to the white spot syndrome virus (WSSV), most only managed to harvest smaller shrimp in 2017."

Santhana added, "Everybody thinks India still produces only headless shrimp. No, we have various value-added shrimp. There have been huge investments made on processing plants which are of international standards. In fact, China has started to import value added shrimp such as PD, Butterfly and EZ Peel from India, demonstrating that India has the capacity as well as technological investments and innovations to bring very high quality shrimp to the markets."

In terms of markets, China and Southeast Asia have emerged as very large importers of Indian shrimp since 2014. Almost 34.8% of exports are to China, followed by Japan, and the Middle East. The US remains the biggest single large importer of Indian shrimp.

Cascading effect of low prices

Santhana described the sequence of events leading to an oversupply of small shrimp and easing prices. "All was well until early in 2018 when we had a massive disease outbreak, predominantly WSSV in March and April. Many farmers had stocked ponds in December 2017 - January 2018. Farmers then harvested their small shrimp for processing plants leading to a supply overload and prices dropping."

There was a cascading effect of lower prices. "In Table 1, there was a drop of almost USD 1.5/kg in May, enough to drive farmers out of business. They then preferred to stop stocking, fearing that if they stocked and harvested in May or June, prices will drop further. With no demand, hatcheries drained away an estimated 1.2 to 2 billion post larvae from March to April 2018. We estimated this industry expected to produce 500,000 tonnes of shrimp, but I think, ultimately, in the first half we produced 380,000-400,000 tonnes only. A raw material shortage is reflected by price increases. Starting in August and September, there will be an acute supply shortage in India."

Santhana added, "Even the farmers with a normal crop went into panic mode and began to harvest quickly. If they had continued the crop, they would have changed the situation." Other countries, Vietnam, Thailand and Indonesia observed the situation in India. "Until May, the price of Indian shrimp in the international market was almost stable, while other countries experienced falling prices."

Profitability and stocking

The decision of the farmer on whether to restock his ponds will very likely be influenced by the potential massive mortality due to WSSV, and by other reasons such as slow growth, *Enterocytozoon hepatopenaei* (EHP), high feed conversion ratio (FCR), low average body weight (ABW) and increased costs of production. Santhana noted, "With white faeces disease (WFD), farmers still have hope as shrimp are not dying. Usually, no farmer will harvest the pond, as they will be hoping for a miracle to push up growth. As farmers usually target 30g shrimp, it may take him almost 5 months with the FCR of 2 to almost 2.5!"

What next: caution and concern

"As much as we have huge areas and huge production, diseases are also very widespread and pose major concerns. What is next? It is without a doubt that we are looking at very high expansion and higher production. There are many new entrants with no shrimp farming experience. Unfortunately, these are investors with no regard for the environment, disease control, etc. Industry stakeholders such as SAP, Vaisakhi Group, feed millers and the Seafood Exporters Association of India (SEAI) want to educate such newcomers on developing a sustainable industry," said Santhana.

Science in Shrimp Farming and Recent Innovations in Hatchery and Production Systems in Vietnam,"

Dr Tran Huu Loc, Founder-Director, ShrimpVet Laboratory, Vietnam, in his presentation said that in Vietnam, managing diseases and the push towards efficient shrimp farming continue to be very challenging. He added, "With the current situation, the use of antibiotics is rising, judging from the rejected containers of shrimp with antibiotic residues. We need to act; we need to have replacements for antibiotics and a safer farming methodology."

"The major challenge of disease in Vietnam is still EMS/AHPND, WSSV, EHP and white faeces disease (WFD) which have become more severe. As for SHIV, we are not sure whether this is already in Vietnam, but we are setting up the diagnostics with PCR," said Loc.

Analysis carried out at ShrimpVet laboratory by Loc showed the clear route of infection with 3 to 5% of live feed (polychaetes) tested positive to AHPND. Recently in Phan Rang where most of the hatcheries are located, this rose to more than 90%, when there was a change in the environment in August. In the case of EHP, an estimated 5% of the polychaetes, oysters and squids were positive to EHP. About 8% of the post larvae samples were positive to EMS. Random sampling showed that about 20% of ponds tested, gave positive results to EHP and close to 15% of shrimp samples were positive to EMS.

"There is evidence that most infections start with broodstock feed. The industry desperately needs replacements for live feed, or methodologies to make them safer such as gamma radiation or frozen products. Transmission of EHP spores is via oral route or lateral infection. Thus, it will be very difficult now or in the near future in terms of EMS and EHP control in hatcheries."

Efficiency parameters

Loc said that based on calculations, farmers cannot make enough profit if they produce 20g shrimp at ADG of less than 0.25g. An ADG of 0.3g is the breakeven point, which is possible with the current genetics developed for fast growth. However, efficiency also starts at the hatchery. The recommendation is antibiotics-free hatchery protocols to produce clean and good post larvae with coefficient of variation of less than 12%.

"PCR diagnostics are so important to check on the critical points: broodstock feeds and post larvae. Diagnostics also have their limitations, especially with AHPND diagnostics. If checking for CFU/mL of less than 10^4, a conventional PCR, or nested PCR will give negative readings. You will need to enrich the sample prior to running diagnostics."

The good, the bad and ugly bacteria

Biosecurity and micro biota balancing are two key points to reduce problems with AHPND. "We start with a completely sterile environment after numerous water treatments and disinfections. On day 1, the *Vibrio* count is zero but will surge to 10^4 CFU/mL by zoea 2-3 stage. Later at PL1-5 stages, *Vibrio* will proliferate with the addition of feeds," said Loc.

"With the addition of some slow-growing bacteria or probiotics, at the nauplii 5 stage, we can reduce *Vibrio* at the mysis stage, and then at the PL stage. *Vibrio* will thrive again with the feeding of *Artemia* and artificial diets. In our environment, we always have three groups of bacteria, the bad, the good and the ugly. Bad are obligate pathogens, such as the luminous and *Vibrio*; they are initially present at low density but will increase rapidly. The good, the probiotics, are the ones we introduce into the system, and the ugly are the commensal bacteria. In our bioassays in the laboratory, there is competition between probiotics and obligate pathogens. The pathogen is efficient and always wins. The message is bioremediation via probiotics is never a remedy for bacterial disease; it is a tool."

Loc suggested, "Before stocking, a jump start is a daily 10^{4-5} CFU/mL inoculation. Refrain from providing the bad and ugly bacteria with nutrients and the rule of thumb is to have the good bacteria at a ratio of 100:1 to that of the ugly and/or bad bacteria."

Managing EMS and EHP at the farm level is similar to that in the hatchery. "The risk factors are overfeeding and microbiota imbalance. Waste management and siphoning are ways to remove potential sources of toxins and nutrients for bad bacteria. Polyculture also helps in microbiota balancing."

Functional diets and EMS

Loc also discussed some results with functional diets which have been positive in reducing the impact of AHPND and WFD. "In the trials in lined ponds, using functional diets and waste water tested positive for AHPND and EHP, gradually shrimp in all the ponds were positive for EMS, EHP and WFD (which most farmers live with), but the survival rate was good at 75% for the control ponds. With functional diets, survival reached 78-96%, the ADG was better and final weight higher. The functional feed with immunostimulants help to reduce infections. I would say that in the past, survival rate of 90% is very normal, but now it's about 65%-70%."

Challenges and opportunities in Ecuador

The industry in Ecuador is challenging global trends and increasing production year on year. Ecuador contributes 50% to shrimp production in the Americas. **John Tinsley**, Technical Director, BioMar Americas looked at "The Road Towards Sustainable Shrimp Industry: Challenges and Opportunities in Latin America from a Feed Producer's Perspective." Securing the economic sustainability of this industry covering 3,070 farms is a social responsibility as it involves, direct and indirectly, around 7% of the working population. Two-thirds of shrimp farmers are small (0-50 ha) and medium (50-250 ha) producers.

Ecuador has shown a consistent track record for growth, from 220,000 tonnes in 2010 to 425,000 tonnes in 2017.

Ecuador vs Asia

In Ecuador, shrimp production starts with nursery stocking of 4 post larvae (PL)/L of sizes 3mg/PL. The nursery rearing is 15-18 days to produce 0.20-0.50g/juvenile. Juveniles are transferred to grow-out ponds at 120,000 juveniles/ha and it takes 100 days to reach 20g under well managed conditions. The average daily growth (ADG) is 0.19g. Survival is 80-85% and FCR 1.5 – 1.8. Profits are USD15/ha-day. Some 3.5 cycles/year is a reality.

"While Asian shrimp producers focus on pathogen exclusion using SPF broodstocks, water disinfection and heavy aeration to maintain stable conditions, we co-exist with the pathogens and the microorganisms in our systems. We use tolerant and resistant stocks, functional feeds to reinforce the immune system and reduce shrimp stress by stocking at low densities. Our yields are around 1 tonne/ha as compared to 10 tonnes/ha in Asia."

Raw materials and sourcing

Feed plays a leading role in the global industry; as aquaculture grows the demand on feed increases. "Today, the trend in the Americas is certification and traceability for established raw materials. We still rely on traditional raw materials. There are opportunities to include alternative ingredients in feed; great steps have been taken by the supply chain to develop such raw materials but their use lags behind other aquaculture markets", said Tinsley. "The future is to focus on raw materials which do not compete directly with stable food resources."

Efficient productivity

Growth rate and survival, is influenced by genetics, environmental conditions and farm management. "Important metrics for Ecuadorian farms are dollars/ha-day and dollars/kg of shrimp and not only FCR and growth rate. The challenge is to improve efficiency and ultimately profitability when shrimp prices are at their most volatile and competition on the global market strongest," said Tinsley.

"A strategy to improve productivity is the nursery phase. Proper use is allowing the industry to improve the robustness of our post larvae transferred to ponds, reducing the pathogen pressure and increasing feed efficiency.

Traditional large ponds dominate production in central and South America. To reduce stress points and triggers for any disease outbreaks, recirculation is used to stabilise environmental conditions and improve productivity. "Some producers have invested and converted farms towards recirculation systems which require a high level of technical expertise and capital investment. But they show improvements in yield and survival."

Since the WSSV outbreaks in 1999, industry learnt lessons and took initiatives to reduce risks by focusing on genetics, management and healthcare. "In the Americas, integrated management strategies to support health and welfare are proven. Production strategies focus on maintaining water quality and preventative healthcare by using functional feeds and robust post larvae. In health assessment and diagnosis, we are learning to be proactive, and today producers are committed to reduce their reliance on traditional medicaments and are looking at alternatives."

Research and development

Our R&D on fish meal replacement in salmon has added knowledge on nutrition, welfare and new technology. Through an improved understanding of the biology and nutrition, FCR has been decreasing and growth rates improving health and the product quality are maintained. Salmon feed prices have been reduced to just over USD 1/kg. This knowledge has been transferred to many species, including shrimp but still need more work.

Another opportunity is collaboration. "Feed producers hold the key position in the value chain. We are responsible for sourcing, transparency and food safety. Feed connects the whole value chain, from farmer to retailer."

SESSION 2: PRODUCTIVITY IN THE SUPPLY CHAIN

Disease threats and managing trigger points

Diseases in Asia are not homogenous. Different countries face different disease challenges. **Anwar Hasan**, Regional Technical Manager – Aquaculture, BIOMIN shared on shrimp diseases in Asia, the probable trigger points of diseases and follow-up production strategies to mitigate them.

"In the past, most of the very damaging diseases in shrimp were caused by viral pathogens, but now it is found that natural bacterial and microsporidian/fungi are major pathogens. During Asia's monodon shrimp era, the main pathogens were WSSV, monodon baculovirus (MBV) and yellow head virus (YHV). Since 2010, the most devastating disease has been bacterial causing EMS/AHPND. Even though the main shrimp species in Asia is now the vannamei shrimp, WSSV is still a major threat. Since 2015, AHPND, WFD, EHP, running mortality syndrome (RMS), infectious hematopoietic necrosis virus (IHHNV) are common for some countries." Only infectious myonecrosis virus (IMNV) is present in Indonesia, but Anwar indicated that in other countries, another virus with similar symptoms to IMNV has been reported as covert mortality disease (CMD).

"Indonesian farmers grappled with WFD while many others in Asia were faced with AHPND. We need to be aware of new emerging diseases. The new challenge is iridovirus in shrimp which has been shown to be very severe in marine fish and probably in shrimp too," added Anwar.

In **India**, with the introduction of the vannamei shrimp, productivity rose from 1 tonne/ha (in 2010) to 3.5 tonnes/ha in 2015. Even at this production level, disease was very present with 80% of ponds were infected mainly WSD, Black Gill Disease (BGD), RMS, loose shell syndrome (LSS), WFD, white muscle disease and IHHNV.

Farms in **Vietnam** have focussed on biosecurity and started lining or semi-lining ponds and use biofloc or semi-biofloc. Nursery phase with zero water exchange is common. "The concern is flushing of waste water into the environment after the pond has had a disease. Antibiotics is also a big concern in Vietnam. Some farms stock more than 200 PL/m^2. Today, the main diseases are EMS/AHPND, WFD and WSD. EHP is also common. Recently, white muscle disease with symptoms like that of IMN but negative to IMNV was reported." Anwar added.

In **Thailand**, the concerns are EHP, AHPND and WFD. Thai farmers have managed well with initiative and innovation. Many farmers try to mimic Thailand regarding their shrimp toilets. Thai farmers also have indoor and outdoor recirculating systems as well.

A major impact on the industry in **Indonesia** has been WFD which, according to Anwar, forced closures of two large farms as well as several mid-size and small farms. "WFD occurred even at low stocking (20 to 40 PL/m^2) with poor biosecurity and water management. WFD is found in many locations." Anwar added, "Indonesia's industry suffered from IMNV from 2008 until 2012. The pathogen apparently disappeared, and producers were happy as 2013, prices were high and other countries were suffering with low production because of EMS/AHPND (Thailand, Malaysia, Vietnam and China). But this year, IMNV is more virulent and occurs earlier during culture. Previously, maximum mortality was 60%, now it can reach as high as 90%. A possible co-infection (EMS, IMNV and WSD) is suspected."

Trigger points

Farmers have been facing a dilemma as they look to deploy various strategies to manage these diseases and to better understand the pathogens present in the farm environment.

"Initially, we manage the likely trigger points adapted from WSD; post larvae, water source factors, predators and some other carriers," said Anwar. "So, we minimise impacts with biosecurity, but disease is no longer caused by one single pathogen. With WFD, we do not know the actual pathogen."

In his presentation, Anwar focussed on three trigger points; stocking density, the trigger factors of disease in healthy shrimp, and managing water quality, including blue-green algae.

"In Indonesia, after experiences with IMNV, farms focussed on carrying capacity. They reduced stocking density significantly, and found the maximum carrying capacity and stocked that number into ponds. In areas surrounded by ponds, keeping to 100 PL/m2 -120PL/m2 or less is suggested. In the management of WFD, low stocking density was suggested as well as zero water exchange."

Anwar questioned whether post larvae stocking size of PL9-11 is the right size, particularly in managing AHPND. A nursery phase will grow post larvae to 3-5g and stock stronger and exposed to pathogen shrimp. "During the nursery, immunostimulants or hepatopancreas protector can be added to counteract WFD or EMS."

The big concern is toxins which can also damage shrimp hepatopancreas. Producers need to be aware of three sources of toxins; cyanobacteria, pathogenic bacteria and contamination in feed. Cyanobacteria and pathogenic bacteria produce endotoxins and exotoxins, while mycotoxins are common in contaminated feed material. He said an Indonesian research found cyanobacteria toxin in water deposited in hepatopancreas of shrimp infected by WFD. Toxins reduce the immune system of the shrimp. "When a blue-green algae bloom crashes, the disease comes in the next couple of days. Either probiotics or chemicals can be treatments; chemicals work faster, but plankton domination changes quickly, releases endotoxins, increases organic matter and promote *Vibrio*s. Probiotics will take 2-3 days," added Anwar.

"Diseases related to white muscle syndrome (IMN, PvN, and/or CMN disease) are more virulent lately. There is the possibility of co-infections. Determining stocking density and/or nursery system is important as a strategy to manage direct or indirect effects of several diseases. As dissolved oxygen and water quality trigger diseases, managing these 2 factors could help farmers to manage the worst effects of diseases. Managing algae has become important to avoid disease outbreaks."

Different horses for different courses

Dr Morten Rye has worked on applied genetic improvement programs for fish and crustaceans for more than 30 years, with extensive experience from Europe, Asia and the Americas. Rye in his presentation with the above title, focussed on genetics as a tool to develop a more targeted shrimp, adapted to its production environment.

"Using the salmon as a reference, we know that all commercial production globally comes from well-designed breeding programs, and that will be the direction for all key aquaculture species," said Rye, while highlighting trends from development of genetic resources for the vannamei shrimp. Shrimp production is characterised by highly diverse production systems-super intensive farming in Asia and very extensive systems in other parts of the world. One critical component to consider is biosecurity, as most farms are located close to each other; water discharged from one farm could well end up entering another. "In shrimp genetics, we have to consider genotype by environment interactions. A specific stock which is well-adapted to one environment may not be the best suited to another."

Today, vannamei is produced in vastly different systems, from freshwater to full strength seawater. They are cultured in a wide range of temperature zones and there are huge variations in the oxygen levels in the systems.

SPF and pathogen exclusion

"Stock introduced to Asia is generally healthy and specific pathogen free (SPF), and there is currently a major focus on pathogen exclusion and a fight to get rid of major diseases. Considering the cycle of repeat disease outbreaks in the region, however, one could argue if this approach has been successful. Today, we realise we also have to modify the shrimp to suit its production environment."

Rye said, that in Latin America, the shrimp have generally been selected for robustness to face the challenges in the less intensive systems. There has been less focus on selection for fast growth rate, but the evolved stock is being developed gradually. The overall approach is trying to live with local pathogens first.

"Because the prevalence of pathogens is high, it has become almost impossible to eradicate. Furthermore, in extensive production systems it is very difficult to modify and control the production systems. While Latin America is adapting the shrimp to the environment, Asia is trying to manage the environment to suit the shrimp. There are significant genetic resources coming to Asia, but since vannamei is a non-native species, most of these are not developed for an Asian situation."

Fit for the environment

Rye believes that Asia under the current strategy is likely to continue to face significant outbreaks of new diseases on a regular basis. "This is because whatever strategy farms have for eradication, there is no way to eradicate all the pathogens affecting shrimp. This has to be considered when developing a sustainable strategy for the genetics work."

The goal must be to develop robust animals that can resist the new challenges. "The way to do this is to face the challenges that is coming down the road, to develop shrimp that can survive and grow well under specific conditions of a location, season or production system. There are tools now from the genetic side to tailor-make products to differentiate for the environments needed."

"The objective of genetics should be to produce animals that are better adapted to local conditions and Asia has to come up with a system to secure long term sustainability. Is it possible to balance the extensive and intensive experiences so that we can avoid this rollercoaster situation typically seen in Asia to arrive at a more stable growth?" The answer is to develop robust shrimp that can resist new challenges, such as using specific pathogen resistant (SPR) shrimp while ensuring that the entering animals are clean, e.g. not bringing new pathogens.

Morten reminded the industry on the difference between SPF and SPR status and that, under any circumstances, there must be a strict quarantine on introduction of new genetic stocks. The system which supplies post larvae must not carry diseases that are not at the facility or in the region and it must start with robust stocks, so that they can face the local pathogens without leading to major problems of diseases. In addition, there should be a more advanced certification system in place, which considers the current situation in the specific region where these animals are used, allowing tailor-made products to better suit the new environment rather than have a very general SPF requirement.

"There is new knowledge on the immune system which is of great interest for genetics. It was believed that shrimp has an innate immune system with no memory, but new results show that there is a highly adaptive system which is open for immune priming. Likewise, is the implementation of genomic selection currently underway in leading shrimp programs expected to further boost the selection response for disease resistance."

Sustainable approaches for vannamei shrimp nursery culture

Stressing the importance of microbial control in the environmental management of shrimp nurseries, **Manuel Poulain**, Key Account and Project Manager at Thailand's INVE Aquaculture, brought attention to the balancing act of a multi-trophic ecosystem approach.

In his presentation, Poulain advocates for low or zero water exchange and covered facilities in the fight against diseases as a way forward in sustainability, both environmentally and economically. "Like many different businesses, the success of a farm is mainly based on risk management," he said covering topics from biosecurity and nutrition to microbial and nitrogen control.

Biosecurity

This is the control of contamination factors which Poulain explained as chiefly water, shrimp as well as other considerations such as crabs, birds, aerosols and people. Limiting water exchange will help minimise risks. The future will require ensuring quality control of post larvae and covering facilities to reduce environmental influences as well as a measure of minimising phytoplankton dynamics. Poulain recommended covered facilities only for super intensive farming, as it may incur considerable capital investment. "The use of a nursery will basically minimise the investment due to smaller pond sizes and a lower risk.

"In a high-water exchange system, especially nurseries, there is 100% to 600% water exchange a day, depending on the type of system." The main strategy is managing the environment through solids removal and bio-filtration. A limitation observed is the difficulty in exchanging water with small animals involved, because of mass clogging. Others include high-energy consumption used for pumping water and nutritional limitations in systems with poor natural productivity.

With bioflocs, activated sludge is a supplementary food source for shrimp. It works by managing carbon-to-nitrogen (C: N) ratio with zero or reduced water exchange and the removal of nitrogen via the heterotrophic population. A drawback is the tendency to accumulate nitrite within new environments and the biofloc system becoming semi-biofloc as farmers panic with rising nitrite levels and take reactionary measures by initiating water exchange.

A multi-trophic approach, on the other hand, uses autotrophic nitrification that does not require a carbon source. Employing zero-water turnover, it is similar to the biofloc system in that it is based on competition. "Limitations we observed is oxygen – we have seen that when you have more than 3kg/m^3 of biomass, it's very difficult to maintain oxygen levels of 3.5ppm or 4ppm. So, we have basically identified feed loading and shrimp biomass as KPI for sustainable nurseries or sustainable farming."

Constraints that crop up with zero or reduced water exchanges range from high Vibrio dynamics, organics and solids accumulation, leading to pathogens to high nitrogen build-up, with a likelihood of experiencing phytoplankton crash. "All these are linked so the approach is holistic as it considers all these clusters in our management.

"In limited water exchange nurseries, in terms of risk, the higher the density, the shorter is the nursery (under 20 days). Usually, we like to transfer animals over 0.3g, otherwise catching with a net is very stressful to the juveniles." Poulain showed a design of a high-density nursery, up to 40 PL/L with 6 x 45m^3 tanks to sustain this system, aeration is by blower of 3.5hp and 65 diffusers as in the case of a nursery in Vietnam. There is shading to lower phytoplankton dynamics.

Nutrition

In feed management, Poulain advises using air blowers to create convection currents that are more efficient as aerators. "Circulation currents are not so good because when you put feed in the tank, shrimp does not grab the feed right away. If you have a current that is too strong, the feed accumulates in some areas and creates a lot of competition for feed between animals – basically this stimulates size variations and drops survival rates.

High-density nurseries show high productivity diluting production costs. Higher nutrition and quality feeds are affordable. The recommendation is a minimum of 15% replacement of daily feed with quality feed. The idea is feed less, feed better. This limits nitrogen build-up and creates more strength with health boosters for the animals. But the down side of high-density nurseries is induced stress, demanding quality immunostimulants as feed coating to boost shrimp immunology.

Microbial and nitrogen control

A hygienic environment is key as a start to microbial control. The primary tool in the arsenal is a high concentration of probiotic bacteria for water conditioning and top coating, using competitive exclusion on two fronts. Firstly, is covering the space with good bacteria. Secondly, is limiting food, starving *Vibrio* out. Nevertheless, problems arise because of different multiplication rates as it takes an average *Bacillus* six hours to multiply, compared to the *Vibrio*'s 20 minutes.

Minimising nitrogen accumulation comes with feed management, quality diets, biofloc and the holistic approach of reduced water exchange. Poulain revealed that over his 20-year experience, the vannamei shrimp can handle up to 5ppm of nitrogen for a time. "Would you prefer 1 to 3ppm of nitrogen, or exchanging water and taking the risk of bringing in white spot disease, early mortality syndrome or *Enterocytozoon hepatopenaei* (EHP)? Before you exchange water, look at alternatives – lower feeding, bottom siphoning or shrimp toilets."

In summary, expenses can be redistributed to cover important purchases such as additional cost of superior quality diets by reducing costs associated with high water exchanges as it reduces contamination risk, water treatment costs and power usage while halving labour costs. "In my opinion, sustainability is biosecurity, plus consistency. I think that is what the industry needs."

Manuel Poulain leading a roundtable on culture, technology and innovation (CTE during the breakout session.

SESSION 3: NUTRITIONAL AND HEALTH INTERVENTIONS

Mitigating diseases through gut health: Options today

A healthy digestive system is essential for animals to maximise nutrient absorption and to minimise the intrusion or interference of pathogens, including bacteria such as *Vibrio* species in shrimp.

"It is especially important to reduce these pathogens in the shrimp gut because they cause huge losses during production," said **Dr Serge Corneillie**, Business Development and Technical Director for Diamond V based in Asia, specialising in aquaculture. "In shrimp farming, several *Vibrio* strains – like *Vibrio parahaemolyticus, V. alginolyticus, V. harveyi,* and *V. vulnificus* – can cause up to 100% mortality."

Today, the use of antibiotics in animal production is under much greater regulatory control. In many countries, it is no longer possible to use antibiotics to prevent disease or promote growth, even though they are cost efficient. Pig production AGP's (antimicrobial growth promoters, including antibiotics) in the feed could show an average 8% improvement in growth and 3% improvement in feed conversion over production without AGP's.

"There are no silver bullets to replace antibiotics. It is proving very difficult to discover or develop a comparable alternative. So nowadays, we try to influence the microbial community in the gut, by reducing pathogens without using antibiotics while promoting more beneficial bacteria.

Options to improve gut health

The modes of action and recent findings for options in shrimp feed, such as use of organic acids, probiotics, immune stimulants, essential oils, and fermentation-based immune support products were described.

The mode of action for the organic acids is to lower gastric acidity (pH), Corneillie pointed out, and the shrimp intestine has pH 7. Organic acids reduce the intestinal pH, which favours the non-dissociated form of lactic acid produced by the *Lactobacillus* bacteria. Only the non-dissociated lactic acid can penetrate the cell wall of gram-negative bacteria and destroy them. Studies show that propionic acid and butyrate (the salt form of butyric acid) added at relatively high concentrations of 1% or 2% are most effective for shrimp.

The mode of action of butyrate is to increase the lower intestinal cell proliferation, reduce inflammation, increase intestinal epithelial integrity, and promote enzyme production, amongst others.

Butyrate improved the growth and survival of shrimp. It reduced *Vibrio* species. However, the inclusion required was 2% to be effective. Butyrate is not 100% stable and requires encapsulation. There are attempts to use specialised butyrate-producing bacteria as probiotics or 'direct-fed microbials' in feed: "Unfortunately, these specialised bacteria are unstable and difficult to grow, even in the laboratory. The transfer from lab to commercial application is still to come."

Other probiotics are widely used in shrimp farms. The mainly gram-positive bacteria showed growth promotion, the reduction of pathogens, improvement in digestibility, and improvement in water quality. *Bacillus* and *Lactobacillus* species seem to be the best organisms. The potential benefits of probiotics are very clear, especially by adding to the feeds, but for feed companies, this is still a challenge as many species are non-heat stable and not easy to use in feed pelleting or extrusion applications.

"Also, while probiotics in poultry and swine production is limited to about five different species, in fish some 50 to 60 species of bacteria have been used. It's important to note that the positive probiotic effects tend to be species-specific and even strain-specific."

Corneillie commented on the debate on whether it is effective to add probiotics to the water: "My take is that if you have an extensive system in a 1 ha pond and the *Vibrio* population is 10^4 CFU/mL, then a lot of probiotics is required to counter-balance the pathogens. Especially as the turnover of *Vibrio* is 20 times faster than *Bacillus*, for example, so it would not be easy for this relatively durable probiotic bacteria to out-grow the pathogens. It is much easier to dose the water in hatcheries and nurseries and the most intensive farming operations."

In terms of immune stimulants or 'boosters', Corneillie said that oligosaccharides and beta-glucans are the most widely known types. "Beta-glucans appeared in the market about 25 years ago in Europe. This type of immune stimulant has a very fast overload immune reaction, which means it requires carefully timed feeding."

An experiment demonstrated one of the challenges of 'boosting' the immune system. In the trial, pangasius were fed two beta-glucans products, a yeast with glucans in the cell wall and a mannan oligosaccharide (MOS). The control group had a 40% survival rate, whereas the beta-glucans group had a 60-65% survival rate. However, following 2 weeks of feeding, there was no longer any improvement in survival."

"This immune overload with beta-glucans," Corneillie said, "occurs not only in fish but also in pigs, poultry, and humans."

By contrast, MOS are more likely to function as an immune modulator and not an immune stimulant: "MOS promote mucous production in fish. The increased mucous layer prevents parasite larvae attaching to fish. MOS also improved the gut structure and gut integrity.

Which one?

Taking an example from the European Union poultry industry, Corneillie described the search for a product to target *Campylobacter jejuni*, a gram-negative bacterium, which is not recognised by the phagocytic cells of the immune system but very harmful to humans. In a 42-day study, three types of products were efficacious — coated butyrate, probiotics, and a natural, microbial fermentation-based, immune support product. The latter type has had success in poultry and livestock production in the United States over the last five years. Researchers found It could reduce prevalence and concentration of several foodborne pathogenic bacteria, including *Campylobacter, Salmonella, Escherichia coli* and *Klebsiella*.

"When those researching *Salmonella* load in US poultry used the immune support product on top of their existing program," Corneillie said, "the prevalence of *Salmonella* was reduced by 56% and *Salmonella* numbers were reduced by 88%. Subsequent university research showed that not only did the immune support product strongly reduce pathogen prevalence and concentration, it also reduced virulence of the pathogens."

However, Corneillie added, there was an even more surprising discovery. The university researchers found that the immune support product restored sensitivity to antibiotics in the pathogenic bacteria: "For example, the antibiotic resistance decreased from 18% to 1.4% in Salmonella resistant to florfenicol.

"In challenge trials with shrimp using the immune support product, we showed that the product reduced *Vibrio* in the intestinal tract. There was an associated strong increase in immune response, with an increase in phagocytic activity.

"Unlike immune stimulants or boosters, the immune support product appeared to increase the capability of the innate immune system to respond quickly to the channel, then return to a normal level of preparedness. By contrast, keeping the immune system in a constant state of stimulation — which is a risk using an immune stimulant — unnecessarily wastes energy and other nutrients and may cause other unintended consequences."

Corneillie concluded, "These are options for good gut health, but we still must do some work in finding the right applications and how to apply them. Presently, microbial fermentation-based immune support technology has great potential in shrimp production, not only for gut health benefits, but because the products of such technology have proven effects in the innate immune system. Again, however, we still must learn more about how such products work in shrimp and other aquaculture species."

Nutritional solution against WSSV

A trial organised in Ecuador offers proof that nutrition may be the healthiest option to controlling the white spot syndrome virus (WSSV) through prevention rather than cure. DSM Nutritional Products Latin America's Regional Aquaculture Manager **Thiago Soligo** discussed the results of some trials in his presentation on "A Nutritional Solution against White Spot Syndrome Virus on Pacific White Shrimp *Litopenaeus vannamei*."

WSSV is the most pathogenic, hitting Latin America at a crucial time during the region's early development of shrimp culture in 1999 and spreading to nine Pacific coast countries. Outbreaks are common during the change in season or rainy season with sharp decrease in temperatures. Chronic mortality can lead to survival rates from 70% to 40%.

Evolving practices

In Ecuador, improved shrimp genetics by generating strains with enhanced growth and disease resistance allowed the industry to recover in 2006 back to pre-WSSV levels. Profit and production levels increased by optimising resources such as the use of water and aquafeed. To produce shrimp again, some producers in Brazil shifted to intensive culture in small ponds (0.1-0.4 ha) and stocking 170-250 PL/m^2, covering ponds, HDPE liners, water recirculation, zero water exchange and biofloc systems.

In Guatemala, producers began to implement hyper-intensive culture using fast growing and disease resistance strains, shorter cycles to avoid low temperature months (November to February) and clean pond bottoms with siphoning. In Costa Rica, the industry aimed at a higher market price by adding value to their products through certification to compensate high production cost conditions in the country.

"Switching to more technology-driven and efficient intensive farming technologies enabled shrimp farmers to increase production in the last few years," said Soligo, adding that farm management and biosecurity to prevent and coexist with shrimp diseases became more important. These best management practices were then adopted throughout Latin America.

Upping immunity

Shrimp have an extremely basic immune system that relies on non-specific or innate mechanisms, as specific or adaptive immune response and related immune memory do not exist. With only this first line of defence in play, Soligo advocated reducing conditions that can suppress immunity, for example, stress and environmental factors. "This could be possible with an increase in control of environmental factors, such as temperature, oxygen, and salinity or pH levels."

In addition to these, he emphasised the importance of proper nutrition to promote health conditions. "Our proposal for a health solution is prophylaxis to improve the immunology of shrimp and resistance to stress and disease. Controlling the disease is better achieved by prevention than cure." He suggested a balanced supply of micro ingredients and immunostimulants as an adequate defence line in support of innate immune system development. It functions optimally and reduces risk of secondary infection.

The key element to assist in immune stimulant development is by achieving synergy between substances to modulate different immune functions. These involve phagocytosis, lymphocyte proliferation and natural cytotoxicity.

Synergy between substances

One important immune stimulating ingredients is nucleotides. It helps cellular proliferation, improving the non-specific immunological response, disease resistance and reduction of stress effects. Research in Thailand showed that nucleotide-rich products supported the resistance of the vannamei shrimp to pathogens, the bacterial *Vibrio harveyi* and viral WSSV. Nucleotide levels used in the trial were 75ppm, 150ppm and 225ppm.

Following results from the trial, a premix boost with increased levels of vitamins and additives was proposed, then tested in the National Marine Aquaculture Research Centre (CENAIM) in Ecuador. Using the premix boost, the two-phase trial was conducted in July 2017. "The first phase was an experimental culture with 3.8g shrimp in tanks at a density of 16 shrimp/m^2 since the usual final density for Ecuadorian farms is 12-16 shrimp/m^2. The second phase was a challenge test using WSSV infected tissues. Information from the trial supported the positive synergetic effects of ingredients used," said Soligo.

"Our concept says the nucleotides enhanced proliferation of the immune cells, which are not able to synthesise nucleotides. The beta-glucans activate the phagocyte response by binding to a membrane receptor or prophenoloxidase system." He added that vitamin C, an important cellular antioxidant, then protects the cells from oxidation, while vitamin E helps the membrane antioxidant to improve cell communication by enhancing membrane fluidity and overall status of the cell.

Soligo reiterated that best managing practices should be adopted to help biosecurity measures to increase shrimp resistance. Among them is the use of a health premix. "We propose the use of a premix boost as a routine throughout the production cycle to achieve disease prevention and stress reduction that can result in better survival. The premix boost can better prepare shrimp to perform during disease events, improving overall health to mitigate the fate of stress with a better immunological start." He ended with a recommendation to introduce the feed for two to three continuous weeks prior to any critical or stressful event.

Meeting farming expectations

Dr Fabio Soller, Technical Director for Asia Pacific, Diana Aqua, Thailand said, "Most of the time, what shrimp feed producers and what the farmers are looking for do not really match. It is normal that expectations are different as we have one group concerned with feed ingredients and another worried about their cost of production and selling the shrimp for a profit." His presentation covered, "Meeting farming expectations: Functional ingredients for modern shrimp feed and robust animals."

The fish meal price is always on the upward trend, albeit today it is not at its highest level but what is hurting feed mills as well as shrimp farmers is the exchange rate. Based on interviews with some farmers, low-cost feeds can contain protein from 31-42%. Thailand seems to have the cheapest feed with Vietnam the highest at USD1.32/kg. Premium feed contains protein ranging from 34- 45% and price variability is large, the cheapest being in Thailand, followed by India and Indonesia.

Feed producers vs shrimp farmers

Feed producers want stability: ingredients with the same profiles so they do not have to reformulate their diets every time. As for the shrimp farmers, they want excellent shrimp growth performance, i.e. shrimp to grow fast at low feed conversion ratios. Feeding behaviour must be visible. Feeds should not pollute water; they should reduce stress and disease, while producing better shrimp quality and robustness. Feed prices must be stable. Overall, they want a sustainable and standardised feed.

"In comparison, sustainability is high on top of demands by feed producers. The reduced use of fish meal is not about price any more but revolving around sustainability. For farmers, sustainability is low in their list of priority. Farmers are more worried about their shrimp surviving so that they have something to sell at the end of each production cycle," said Soller.

In the 1980s, marine ingredients comprised 36-60% fish meal, but now only 5-25% is used, depending on the species cultured. The transition from high levels of marine ingredients to low levels in feed comes with the removal of soluble nutrients (vitamins, antioxidants and water-soluble peptides). Filling the gap is starch and plant ingredients with anti-nutritional factors. At the same time, ingredient quality has increased as producers focus on studies on digestibility. The attention now is on better formulations.

Focus is also on functional ingredients such as vitamins, antioxidants, minerals, botanicals and enzymes, all of which promote health, boost energy and prevent diseases.

Functional protein hydrolysates

These are very important in shrimp feed when the desired attributes are attractability and palatability. There are also nutritional (growth) and health attributes. Protein hydrolysates consist of soluble protein and peptides. Small peptides below 1,000 Daltons (Da) should be considered as bioactive and play important roles in the organs of fish and shrimp. The production process and specifications have been described in Soller et al., 2018 (Aqua Culture Asia Pacific, July/August 2018, p36-40).

Comparing with other meals, "Fish meal has about 70% of soluble protein and 9% of the total protein are small peptides. These are the most bioactive fractions of fish meal which are not found in alternative raw materials. Blood meal for example, has about 72% of soluble protein but only 3% are small peptides. Plant proteins which include soy protein concentrate, wheat gluten and wheat meal, are not very water soluble and contain very small percentages of <1000 Da soluble peptides."

Health interventions

Bioactive peptides in the diet of shrimp will activate the innate immune response with the production of lysozyme and antimicrobial peptides to challenge bacteria. These include catalase (CAD) and superoxide dismutase which are antioxidant enzymes. Soller described some growth trials in Thailand and Colombia with the marine shrimp.

The aim of an acute hepatopancreatic necrosis disease (AHPND) challenge trial conducted in Thailand was to see how shrimp responded to stress and bacterial infection. Shrimp fed with the treatment diets were challenged with immersions of *Vibrio parahaemolyticus* bacteria twice. "The treatment diet had 3% tuna hydrolysate. In another treatment diet, we top coated commercial feed containing 56% plant protein with a high dosage of vitamin C (1.5%). This was to compare if the vitamin works to fight stress or fight off disease with the animal's antioxidant capability," explained Soller.

In this 4-week trial, there was no significant difference in growth between the control and vitamin C diets. "But shrimp fed the hydrolysates grew 8.6% faster. It could be due to attractability and high feed intake."

However, in the AHPND challenge, there was higher survival of shrimp (70%) fed the tuna hydrolysate. There was no difference compared to shrimp fed diets with vitamin C, but shrimp fed the control diet showed lower survival at 60%.

Investing in feeds

Soller explained that for the farmer, the barrier to the use of functional ingredients is price of feed. "With addition of a functional hydrolysate, the feed price will increase marginally. But we showed that survival was better at 67% and compared to the control diet, the increase in profit reached 52%."

In another trial conducted at Jeju University, South Korea, the growth performance of shrimp fed diets where the squid liver powder (SLP) was replaced with hydrolysates, was compared to the control feed with 5% SLP. Two treatment diets had inclusion of shrimp and tuna hydrolysates at 1% and 1.5%, respectively.

"There was no difference in survival rates between the hydrolysate treatments (82-83%) but weekly growth was 0.89g in SLP diet and 1g to 1.04g with the hydrolysate diets. In these trials in clear water systems, the biological FCR improved to 1.36 and 1.40 with hydrolysate diets compared to 1.57 in the SLP diet. Both feed and protein efficiency improved with the inclusion of shrimp and tuna hydrolysates, even if the total marine protein content of these treatments remains less than for the SLP diet."

Investing in alternatives for shrimp feed

While soybean meal may substitute marine protein meals in shrimp feed formulations, it creates nutritional gaps. At TARS 2018, Aqua Lead Scientist for Nutriad, Spain, **Dr Waldo Nuez-Ortin** looked at what it takes to upgrade the nutritional value of shrimp feeds in his presentation "Sustainable Shrimp Feed: In Search of Novel Ingredients and Functional Additives to Power the Shrimp Feed of the Future".

He covered novel ingredients with more nutritional value than conventional vegetable-based ingredients, as well as functional feed additives that can be combined with them or with traditional

plant-based protein meals to enhance the nutritional value of shrimp feed.

As a prelude, Nuez-Ortin gave results of a survey on trends in commercial shrimp feeds in India in 2016 versus that in 2014. Major changes were in omega-3 long-chain polyunsaturated fatty acids (n-3 LCPUFAs) and cholesterol, decreasing by 16% and 24%, respectively. He also noted that feed samples contained 10-15% fish meal, lower levels than in the past.

Novel ingredients

Plant-based feeds require supplementation with essential nutrients such as cholesterol, amino acids, and trace elements to compensate for the nutritional gaps introduced by the replacement of marine ingredients.

There are transgenic oil seeds high in n-3 LCPUFAs with relatively low production cost. Camelina and canola oils with the introduction of genes from microalgae and yeast can produce high levels of DHA and EPA. Most microalgae oils will have high DHA levels (17-28%). However, a major drawback is still a lack of cholesterol, which shrimp cannot synthesise, that needs to be sourced elsewhere. Soon to be available is a microalgae oil produced by a multinational with 32% DHA and 16% EPA but with low cholesterol content relative to fish meal.

As a protein source, soybean meal still seems to be at the top of the list due to supply, pricing and nutritional characteristics. Hydrolysates can work with soybean meal. Free amino acids, protein and small peptides in hydrolysates have the ability to provide a nutritional balance between protein solubility, attractability, palatability and additional functional properties, while attenuating oxidative stress with possible immune-related properties.

Insect meal is another promising alternative. Protein content can range from 30% to 80% in some species with a generally well-balanced amino acid profile. Limitations, however, are with total sulphur amino acids. Although, high in lipid content, there is no trace of n-3 LCPUFAs unless insects are grown on a substance high in these essential lipids. Similarly, single cell proteins such as bacterial biomass is receiving considerable attention due to rapid growth, high protein content and immunity to climate influence.

Adding value to shrimp feeds

Once nutritional inputs for growth and health are optimised, the next step is finding solutions to maximise the absorption and utilisation of nutrients from new ingredients, such as digestibility enhancers. This is where functional feed additives come in.

Bile salts are important in the digestion of fat in vertebrates; however, they are absent in shrimp, so why bile salts for shrimp? First, as digestibility enhancers because of their emulsification properties," said Nuez-Ortin. "This improves digestion and utilisation of lipids." Secondly, as a nutritional supplement, because the steroidal structure in bile salts in the form of bile acids can to some extent replace cholesterol as precursor of the moulting or ecdysteroid hormones.

To address anti-nutritional factors such as phytate and non-starch polysaccharide (NSP), Nuez-Ortin proposed the use of microbial phytates in shrimp feeds to improve the availability of phytate-bound phosphorous and nitrogen. Carbohydrases are seen as alternatives to gain access to fat, protein and starch as well as improve protein and energy digestibility. That the combination of two types of carbohydrases, namely xylanases (XYL) and arabinofuranosidase (ABF), has been found to improve overall carbohydrase activity by more than 35%. A study showed 50% soybean meal and 26% whole-wheat supplemented with the addition of 200mg/kg of the enzyme cocktail improved protein, energy digestibility, and generally positive weight gain and feed conversion ratio (FCR).

Nuez-Ortin concluded, "More work is needed to scale up the production of novel ingredients. Novel oils are rich in n-3 LCPUFAs but low in cholesterol so we still need other sources of cholesterol. With bile salts, we can improve digestion and utilisation of essential lipids and supply a replacement for cholesterol or an alternative precursor for ecdysteroid hormones."

Cherry Anne Silva, Novus International (left) with John Capellan Nealega, Luningning Febelitas Ubasa Pascual and Diomede Cubal Bucog Jr, Santeh Feeds Corporation, Philippines.

SESSION 4: REVIVAL OF THE BLACK TIGER SHRIMP

WSD-resistant monodon shrimp

In her presentation "WSD-Resistant monodon shrimp: Part of the solution", Professor **Grace Chu-Fang Lo**, National Chair Professor, Department of Biotechnology & Bioindustry Sciences, National Cheng Kung University, Taiwan, discussed the difficulty in controlling WSSV and the R&D work to produce F3 generations of resistant lines of black tiger shrimp *Penaeus monodon* with additional desirable traits to enhance its commercial profitability.

WSD is a global pandemic, with reports of outbreaks even in areas once free of WSSV. Lo detailed the difficulty in controlling the virus. "WSSV has many unique properties. It has very broad host range and replicates very rapidly in shrimp. After replicating successfully, the virus can spread horizontally, and vertically from broodstock to offspring. When shrimp are stocked in ponds with a WSSV carrier with a low level of infection, replication of the virus triggered by environmental or physiological stress, will lead to a crop failure."

WSSV expresses anti-host defence genes at all stages of infection and also has a wide range of hosts. Among them, copepods and hermit crabs which although healthy looking are heavily infected; the virus load is much more than in heavily infected shrimp. This was demonstrated by feeding a clean broodstock in the hatchery in Vietnam with hermit crab and within 2 days, the broodstock was heavily infected. "The standard recommendation is to use SPF seed stock and good biosecurity practices, but even so, it is very hard to guarantee that any commercial system will remain WSSV-free."

The arms race

This is how Lo described the combat between virus and host (shrimp). The virus has 2 fundamental strategies and objectives; it accomplishes a step necessary for infection and replication, and simultaneously overcomes specific cellular defences initiated by the host. The defence mechanisms used by the host to stop invasion attempts by the virus and counter mechanisms that are used by WSSV to infect the shrimp host, have been the subject of research on WSSV at the NCKU laboratory for the past 2 decades.

"Shrimp ROS or reactive oxygen species is an important line of defence designed to kill an invading pathogen, but the virus easily neutralises the host's ROS defences at the initial stage of infection. The shrimp uses its iron withholding defence mechanism which the virus then counter attacks with protein PK1 to defeat this withholding defence mechanism by interacting with host ferritin," explained Lo.

"Usually in response to stress, defence proteins (e.g. NFkB and STAT) will be activated and move to the nucleus to trigger the production of the immune response-related protein. However, if the WSSV genome is present in the cell, the WSSV IE1 gene hijacks this activated STAT and triggers replication of the virus and thus a full outbreak of WSD occurs."

In broodstock, Lo noted that the levels of activated STAT increased post-spawning. This stress of spawning triggers a rapid increase in the virus. Before spawning, the virus was present at 10^1 (copies/µg DNA) and after spawning, in just a few hours it rose to 10^7. Consequently, successive spawning becomes very rare and usually the shrimp dies after a single spawning. So, it is a losing battle with shrimp infected with WSSV. "One would think that to successfully control WSD, it is just to monitor and survey the presence of the virus and then quarantine, or otherwise keep separate the virus and its shrimp host," said Lo. "But this is often not the case.

"WSSV is present almost everywhere in the environment. Looking beyond diagnosis and quarantine, we need to have the host most successfully defends itself against WSSV and a solution might be resistant shrimp."

WSD-resistant shrimp

This work is carried out at the NCKU's Center for Shrimp Disease Control and Genetic Improvement. It has a shrimp genome biology laboratory, a shrimp disease laboratory and reference laboratory for white spot disease and recently, AHPND. The two new breeding centres each have facilities for the complete maturation cycle, multiplication for shrimp family of interest, hatchery and nursery facilities. It has a high level of biosecurity using recirculated water with smart IoT water quality monitor system for broodstock maturation. A central detection system monitors hourly temperatures, dissolved oxygen, salinity, ORP and pH and real time water quality. All shrimp in this centre are at least SPF.

Firstly, Lo explained, "The difference between WSSV-resistant shrimp and WSSV-tolerant shrimp is that in tolerant shrimp, although the virus does replicate, the infected shrimp is still able to survive. What we are primarily interested in is resistant shrimp; shrimp in which the virus is unable to replicate."

It has been well documented that WSSV replication is supressed in shrimp cultured at 32°C water temperature. But at transfer of shrimp to lower water temperatures (25°C) the virus replicates very rapidly. "The virus is not being killed at 32°C, but its replication is being suppressed. We then looked at some factors that are critically different between these two temperatures," said Lo. "We identified the host genes that are critical for virus replication. So, we have 152 candidate genes related related to virus replication."

Broodstock was collected from a wide range of habitats to obtain genetic diversity, confirmed as SPF shrimp and offspring were tested for resistance by WSSV challenge tests. Those in the population showing resistance were grown to broodstock. "Unlike breeding programs that are limited to a single source population, non-exclusive collaboration agreements giving simultaneous access to different populations of shrimp should have a multiplicative effect to produce stronger resistance," said Lo.

To date, the centre has WSD-resistant shrimp over three generations. "The next big question is will the WSD resistant trait pass on to subsequent generations? The answer is yes. In the F1 generation phenotype, it is 17:13 resistant: susceptible. In the F2 generation, it was confirmed that resistance can be passed on to the subsequent generation. The population of resistant shrimp can be increased in subsequent generations".

The message Lo brought across is, "Production of resistant shrimp is just part of the solution. In the breeding centre, we support the resistant shrimp through their complete life cycle using an indoor culture facility with a high level biosecurity. In commercial farms, we need to improve biosecurity for grow-out ponds, a stable ecosystem and an ideal feeding regime."

The shift to black tiger shrimp

In Malaysia, since late 2017, there has been a renewed interest in farming the black tiger shrimp and **Catherine Lee May Ying**, Senior Manager, Group Corporate Sales & Marketing at the shrimp farm, Blue Archipelago Bhd, Malaysia, discussed the "Push and Pull in Black Tiger Shrimp Farming."

Malaysia started its commercial shrimp farming industry in the 1980s with the black tiger shrimp, which in turn developed its shrimp processing industry. WSSV wiped out its farming and vannamei shrimp, in 2005, gave shrimp farmers new hope. Fast forward to the end of 2016, high offer prices for both vannamei and black tiger shrimp, mainly because of persistent disease problems with the vannamei shrimp and the weak Malaysian ringgit, encouraged exports. We had one of the highest local prices for our shrimp. In 2017, it rose to MYR 29/kg (USD 7.25/kg) for 14g vannamei shrimp. Prices for 25g black tiger also rose to MYR 36/kg (USD 9/kg)."

After March 2018, the price gap widened, with imports of vannamei shrimp coinciding with the harvest in southern Thailand and the relatively cheap imports of Indian shrimp. "However, prices of black tiger shrimp remained stable and high. Processors saw the opportunity to export live frozen, or live cooked premium quality black tiger shrimp. They also could offer premium price for harvesting live shrimp," added Lee.

This was most evident in 2017 and mainly with farms in the northern state of Perak. Lee said that the reason given was the failed harvests with the vannamei shrimp and farmers trying their luck with the black tiger, which was surprisingly successful. In early 2018, with the large drop in global vannamei shrimp prices, processors refused to buy vannamei shrimp. Discouraged, farmers did not restock ponds. But the export price for black tiger was relatively stable. Price became the pull factor.

Malaysia has a relatively high local shrimp consumption and processors usually compete with local wet market buyers. When supply exceeded demand with imports, there was no competition to buy shrimp and local prices dipped. The advantage in Malaysia is the export of live, live frozen and live cooked shrimp to China. This became the competitive edge for farming black tiger shrimp.

Vannamei versus black tiger

Lee compared costs of farming both shrimp at a 17-pond farm in Perak. With the vannamei shrimp, stocking at 100-120 post larvae (PL)/m^2, harvests reached 5-6 tonnes/ha. The domestic market demands 14g, harvested within 60 days of culture (DOC 60). Ex-farm price is MYR 19/kg (USD 4.75/kg). In comparison, the black tiger shrimp grown to 25g after DOC 110-120 has an ex-farm price of MYR 32/kg (USD 8/kg). "Based on the cost of production of MYR 15/kg, for the vannamei shrimp, the farmer profits around USD 1/kg, but for the black tiger, the margin is almost MYR 14/kg (USD 3.5/kg) when the cost of production is MYR 18/kg (USD 4.5/kg). The revenue per pond basis is 35% higher with black tiger shrimp farming, if the farmer is successful."

However, there are biological factors. The vannamei shrimp growth rate is linear but for the black tiger shrimp, during the first 55-60 days, growth is slow at 0.14g/day, after which it jumps to 0.40g/day. Farmers who have failed in black tiger farming looked at growth rates and saw the slow growth at DOC 50s. They then made the decision to cut losses rather than wait for growth to pick up. The decision depends on the risk appetite.

Risk appetite

How much risk will a farmer take? Lee presented a scenario of a farmer farming both shrimp up to 50 days. At DOC 50, the vannamei shrimp size is 8g which will fetch an ex-farm price of MYR 12/kg (USD 3/kg). At 50% survival, the production is 2 tonnes/ha and revenue reached MYR 24,000 (USD6,000). If cost of production was MYR 7/kg, the profit would be MYR 12,600. However, with the black tiger shrimp, in 50 days, the size will only be 6g which in the case of the Malaysian market is usually not saleable. Selling even at MYR 4/kg (USD 1/kg) still meant a loss for the farmer, even if survival rate was 70%.

The turning point

"For the farmer, where is the turning point? With a successful crop to DOC 100, the size is 18g for both shrimp with some partial harvests. The final crop for vannamei shrimp can reach 7.2 tonnes/ha at stocking density of 100 PL/m^2 and survival of 80%. Ex-farm price Malaysia is MYR 22.25/kg. The margin is MYR 7/kg. But at DOC 100, the black tiger shrimp reached 28g with ex-farm price of MYR 35/kg, but based on the stocking density of 40 PL/m^2, the biomass is about 4.5 tonnes. Profit-wise, it is the same for either shrimp," Lee pointed out.

There is also the question of post larvae supply and genetic characteristics. Lee explained that in Malaysia, post larvae are from genetically selected broodstocks; Moana, CPF and from Madagascar, Mozambique and of unknown origin. Availability of a specific source of post larvae has been an issue in Malaysia and may be further aggravated by the news that farmers in southern Thailand are switching to farm the black tiger shrimp. "Currently, the preference is for Moana post larvae which farmers say is fast growing, has a slimmer head, and is favoured by processors for fresh frozen products. It is however not suitable for cooked products as there is colour variation. Farmers also like the Mozambique origin black tiger shrimp, because of the large head which adds weight and the even colouration suits live cooking," said Lee.

"Export price continues to be attractive and with the weak currency, processors will continue to demand for black tigers which will push farmers to this shrimp. For the processors, black tiger shrimp will still be attractive, especially when in 3Q and 4Q, they know prices will increase, as it happens every year."

Lee concluded, "Whether it is black tiger or vannamei shrimp, the choice made will be an interplay of factors; both price and biological factors."

SESSION 5: INVESTING FOR THE FUTURE

An investor's perspective

Tim Noonan, Enterprise Strategy Lead, Cargill Animal Nutrition, based in the United States, shared, from an investor's perspective, why it has been so difficult to attract equity capital to Asia's shrimp aquaculture industry. He provided numerous insights into the characteristics that investors seek before they invest in such an industry.

Noonan's presentation began by outlining five key questions. "First, what is the level of investor interest in Asia's shrimp aquaculture industry today? Second, what must be true in this industry if investor interest is going to scale upwards in the future? Third, are there lessons that wex can learn from Norway's salmon industry, or do other emerging markets (such as Chile's salmon industry) or other proteins (such as pork or poultry) provide better examples for how capital might be attracted to Asia's shrimp industry?" He added, "What historical risk or perceptions of risk could we mitigate differently today, perhaps through application of new technologies?" And lastly, "What principles might form the basis for a new paradigm that would increase investors' confidence in the shrimp aquaculture industry in Asia?"

Investor interest in shrimp aquaculture

Noonan then projected two bar charts showing year-over-year changes since 2001 in the global production of two un-named aqua species. The first chart showed consistent, mostly single-digit production growth, while the second chart showed much greater volatility, with several years of 20+% growth and several years of negative 6-10% growth. He asked the audience to put on their investor hats and decide which of these two aqua protein industries would they invest in? To his surprise, a significant majority of the audience chose the second chart – the one with much greater volatility. Noonan then revealed that this chart depicted global shrimp production, whereas the first chart had depicted global salmon production (historically, significantly more institutional investment has been directed toward the salmon industry).

However, during the last 24 months, there has been a notable increase in shrimp investment globally. Noonan highlighted several relevant transactions, including: salmon and seabass/bream producer Cooke Aquaculture's acquisition of Seajoy in Honduras; Charoen Pokphand's investment in Brazil's Camanor; and Toronto-listed High Liner's purchase of U.S.-based Rubicon. "We know that numerous challenges have constrained investment in shrimp aquaculture. But these recent transactions make me optimistic that investors are recognising new ways to mitigate many of those challenges."

Target of investors

Institutional investors focus on the six largest shrimp producing countries in the world (India, Ecuador, Vietnam, Indonesia, China and Thailand), but their perceptions of these emerging markets–beyond the widely-discussed disease risk – have limited their investment activities. Historically, the shrimp industry in all of these countries has been highly fragmented with few examples where consolidation across countries or within segments of the value chain has produced financial synergies. These countries have also faced macroeconomic headwinds, with currency volatility, limited debt financing markets and high interest rates. Noonan explained, "Balance sheet efficiency can be an important contributing factor to investors' returns. Typically, a company is acquired using a prudent combination of debt and equity; the cost of that capital has been very high in most of the world's largest shrimp producing countries. As a result, it has been difficult for shrimp producers to consistently earn more than an investor's cost of capital, especially if that capital has been USD-denominated."

In addition, the shrimp investment targets in these markets are largely privately-held, often family-owned businesses with limited experience raising capital from institutional investors. "This requires a reciprocal, sometimes time-consuming, but critically important process where trust is developed between an owner and investor. When accomplished successfully, the owner and investor have a shared vision and business plan, agree up-front on the uses of invested capital, complement each other's capabilities, assume the good intentions of the other party, and understand each other's time horizon – meaning, does either the owner or the investor intend to exit its shareholding down the road and, if so, when?", said Noonan. "Investors won't be happy to hear that a disease is killing shrimp in your pond, but they can – and did – accept that risk when they invested in you. But they cannot accept a breach of trust."

The salmon industry as a role model?

Noonan does not necessarily believe that the Norwegian salmon industry should be a 'North Star' for Asia's shrimp aquaculture industry, given the substantial differences between Norway and Asia. He did note the success with which salmon companies on the Oslo Stock Exchange (OSE) have attracted investments. "Oslo remains unique amongst stock exchanges globally: it has sophisticated industry analysts and long-term investors who specialise in the seafood and aquaculture sector. This is the type of investor that Asian companies should try to attract when they raise private or public equity or debt."

Since Asia's shrimp aquaculture industry cannot control the pace at which regional financial markets develop, Noonan encouraged the audience to remain focussed on what is within their control. "Ignore the noise; instead, focus on your customers and the business fundamentals that drive profitable growth for them and you. Alibaba founder Jack Ma has said, 'Opportunity lies in the place where the complaints are.' Listen closely to the complaints of your customers and the end-consumers of your shrimp. First, address those spoken complaints. Then, challenge yourself to meet your customers' un-spoken needs. If you can do that, you will find that you have also addressed potential investors' needs and they will come to the region."

New paradigm

"Innovation begins with understanding data. In our industry, sometimes claims about production volumes or growth rates or profitability are based on heuristics – biases of intuition – or even aspirations. From the perspective of the investor, those companies that are able to aggregate, analyse and interpret real-time data will be best-placed to accurately and quickly diagnose a problem, intervene to limit the consequences, and re-engineer the processes or systems that created the problem in the first place." Noonan expects that digital tools – like Cargill's iQuatic™, which delivers real-time decision support through artificial intelligence (AI), machine learning, and Internet of Things (IoT) integration – will play an increasingly important role in helping Asia's shrimp participants make their most important decisions - predicting customers' needs, optimising business fundamentals and benchmarking performance.

Noonan concluded, "If we think first about the needs of our customers, and if we utilise the many new tools that are available to us, there is no reason that Asia's shrimp industry cannot provide what seafood investors seek – a product that is healthy, that is farmed and processed responsibly, and that is economically viable. This is the new paradigm."

A shrimp's eye view: Nutrition modulation

In the future, the industry will be looking at modulating nutrition to fit into handling stress and immunity for the shrimp. In his presentation, "A shrimp eye view: Nutritional modulation to immune function," **Dr M A Kabir Chowdhury**, Global Program Manager – Aquaculture, Jefo Nutrition, Canada said that disease prevention will be achieved through nutritional modulation to match changing shrimp farming practices. "As we continue to put more pressure on our farming systems, we need to understand more on the mechanisms of immunity."

In Asia, there is intensification and accompanying these, disease outbreaks occur every few years. "Low-intensity traditional systems of farming such as those in Latin America induce less pressure and consequently, has lower risks. Despite high margins, overall profit per unit area in these systems is low compared to the intensive systems. Because of low gross-profit, in Asia, it is difficult to roll-back to traditional farming systems. Therefore, the important question for Asia remains: how do we manage the intensive production systems with high gross-profit per unit area that is associated with high risks? Inability to minimise these risks puts a lot of stress on the animals, and at the end, on the farmers."

Shrimp immunity is a black box

In dealing with stress and anxiety in animals, "We can only modulate in a better way if we understand how it works. If we just copy and use solutions blindly, there is a cost element and the solutions are not cheap," noted Chowdhury.

There is a general understanding that shrimp has natural or innate immunity, where the cells not only engulf and destroy any invading microbes but also release proteins that activate other parts of the immune system. "We long believed that they do not have adaptive immunity; immunity that develop only upon exposure to antigens and can be carried over from generation to generation. Only recently, have there been studies to show that invertebrates can have adaptive immunity. This needs to be further explored."

Chowdhury described the two innate immunity pathways and selective responses. The toll pathway is stimulated mostly by viruses, fungi, gram-positive bacteria, lysine-type peptidoglycans and some gram-negative bacteria with lipopolysaccharide cell walls. The immune deficiency pathway is mainly modulated by gram-negative bacteria and creates the intracellular immune signalling.

Melanisation is the principal innate immune response. Recognising foreign materials, there is a proteolytic cascade where some metalloproteases are involved and activation of pro-phenol oxidase (PRO-PO) enzymes to create melanisation. "A recent, very interesting finding is anti-lipopolysaccharide factors or ALFs, which have been well-studied in the black tiger shrimp. These are very active against filamentous fungi as well as gram-positive and gram-negative bacteria. But to date, this information is still at the research level."

Cellular responses

There are three types of cellular immune responses against viral pathogens in shrimp: phagocytosis, apoptosis and RNAi. In phagocytosis, macrophages engulf, and then digest cellular debris and pathogens. "Apoptosis is the programmed cell death, a natural response to viral-replication and to eliminate virus infected cells. This is when farmers see shrimp dying. RNAi destroys viral RNA."

Lastly, reverting to adaptive immunity, there is hope for the industry. Chowdhury referred to some recent research which showed situations of adaptive immunity with shrimp and crustaceans. "One on them was on teaching shrimp self-defence to fight infections and the other showed three generations in *Artemia* with some immune characteristics."

Feed-based solutions

There is a range of nutritional solutions available, including beta glucans, mannan oligosaccharides, nucleotides and lipopolysaccharides. Acting on gram-positive or gram-negative bacteria are antimicrobial peptides (AMPs) and beta glucans binding proteins. "Antimicrobial peptides come from different sources and identifying those with bioactive properties is important. Protease is also in the immune system and all these, including organic acids and probiotics, act to modulate the gut microbiota which can produce antimicrobial peptides in the gut."

Chowdhury underlined that there is no one magic solution and understanding the whole system (farming practices, existing environmental conditions, etc.) can help industry to find solutions.

Finally, "The focus for all stakeholders is growth. We have already gone through genetics selection for fast growth, but the modern farming system is very stressful for the shrimp. So, we need to better manage stress in shrimp and shrimp welfare to secure better survival and better economic outputs."

The Thai shrimp model

In a joint presentation on "Towards Production Efficiency: The Thai Shrimp Model", **Dr Suraphol Pratuangtum**, current President of the Thai Marine Shrimp Farmers Association and **Soraphat Panakorn**, Technical Service Manager-Aquaculture with Novozymes Biologicals & Vice President, Aquaculture Business Association (TABA), outlined the changes during the critical periods in Thailand's shrimp farming industry: before the early EMS outbreak in 2012, facing EMS (2012 to 2016) and post-EMS. They described the changes in farming technology and practices and on knowledge exchange when seeking solutions at the farm and community levels for better production volumes and efficiency.

Stakeholders, in Thailand and elsewhere often asked whether Thailand's shrimp production could return to the peak volumes of 600,000 tonnes achieved in 2010. "With our experience in shrimp farming and our knowledge of the industry, we do not expect production to go back to this volume. Aside from changes in farming practices, we are also very limited in land. EMS hit the industry very badly, partly because we produced too high a volume in a very short time," said Suraphol.

Moving from art to science

Some 30 years ago, there was little need for science and scientific support. Farmers merely pumped in water, stocked the pond with post larvae, fed the shrimp and then harvested the crop. However, 20 years later, with disease outbreaks, farmers needed PCRs to detect diseases. Then 10 years ago, with more diseases, more science was required in shrimp farming. "In the future, it is crucial that science be alongside the art of management, to keep shrimp survival rates high. In 2014, even though *Vibrio* parahaemolyticus was easily detected and Thai farmers learnt

crucial lessons, hatchery operators still used fresh or live feed to raise broodstock in earthen ponds. This is very risky and an easy way to transmit the disease vertically."

Changing to adapt

"In the shrimp farming business, we have often advocated a need to adapt and change proactively. The question will be how and when to change. We have been adapting; when farmers faced a serious problem, farmers and other stakeholders together handled one crisis after another. Our adaptations became a role model for industry elsewhere to follow." The team described changes in farming practices during the three crises and the concurrent roles of the shrimp farming community to effect change nation-wide. Both played significant roles to raise production from the low of 180,000 tonnes post EMS to the current 300,000 tonnes.

Golden pre-EMS era

During this golden era, most farms stocked 50-200 post larvae (PL)/m2 in earthen ponds. Feed conversion ratios (FCR) ranged from 1.3 to 2.0 with low production costs. Long-arm aerators at a ratio of 300- 400kg/hp provided enough dissolved oxygen for survival to reach > 80%. The focus was on phytoplankton for water colouration. Post larvae efficiency (tonnes/million PL stocked) was good at 8 to 10 tonnes. Production success rate was more than 90%. Using these practices, production rose from 400,000 tonnes in 2006 to 600,000 tonnes by 2010. Farmers in the south had the Surat Thani Shrimp Club and those in the east, the Chantaburi Shrimp Club. The exchange of information was limited to shrimp conferences. Thailand had 25,000 farms, mostly small-scale. Farm operations were usually left to semi-skilled technicians.

Facing EMS

At the peak of the EMS outbreaks, production dropped to 180,000 tonnes in 2013. To manage EMS, industry changed farming protocols, resulting in better production volumes at 230,000 tonnes by 2016. To survive the crisis, farmers started to share information and farming techniques. Farmers were more open to information exchange. More medium-scale farms emerged as many small-scale and large farms could not survive under the crisis.

At the farm level, to compensate for lower survival rates (50-70%), some farmers increased stocking density to 100-300 PL/m2. But FCR rose to up to 2.5 and cost of production to USD4/kg. Aero-tubes were added to increase the pond water DO. Farms began to install central drainage systems for sludge removal and studied three phase farming to include nursery systems. Closed systems and recycling of pond water was practised so as not to introduce pathogens, discharge contaminated water into shared resources and avoid being blamed for any spread of diseases. Farms also converted several culture ponds into reservoir and treatment ponds. Post larvae efficiency went down to 3 tonnes/million PL. During this time, farmers prioritised post larvae quality.

Post EMS

During this period of recovery, FCR improved but production costs remained high with multiple types of aeration systems to increase DO. Small size shrimp (80-100/kg) were harvested. Farms recycled water and did not take any risks in sharing water with other farms. Pond sludge was removed quickly. Post larvae efficiency improved to 6-7 tonnes/million PL.

Thai shrimp farmers modified culture practices, began to recognise pond carrying capacity, individual farm conditions, effects of farming practices on the environment and shrimp market forces. Each farmer quickly developed his own system of farming (i.e. in terms of stocking density, technical skills, pond carrying capacity, conditions and location). The Federation of Thai Shrimp Farmers brought all clubs or organisations of farmers under one umbrella. Together, the industry brainstormed at regular meetings held every 3-4 months and whenever they faced a new problem to find solutions. The number of farms dropped and the number of farmers was reduced to 7,000; more medium-scale farms survived, each usually with 10-20 ponds. Some farmers began to do their own marketing of shrimp.

Today, there are many variations in stocking density; some prefer to go for lower density such as 50 PL/m2 to secure successful crops consistently. Soraphat said that small pond sizes are better with clean water and probiotic management systems. Although post larvae efficiency rose to 8 tonnes/million PL, the priority is now on production costs.

The team concluded that today, the Thai shrimp farming industry has become more stable and standardised than before and has a positive future. Over the years, Thai shrimp farmers have learnt that farming techniques cannot be copied, but they need to learn from the success of others and modify the techniques to fit their own farming conditions. They now know that success comes with the open sharing of knowledge and working together to find the right solutions.

First row, from left, Malaysians: Benjamin Yeo, Behn Meyer Malaysia; Jeffrey Lee, Kembang Subur; Tee Hock Koon, THK Sales & Service (M); Chia Song Kooi, QL Resources; Anuar Sani Abdul Rahman, Blue Archipelago; Benny Ng, Kembang Subur; Zuridah Merican, Marilyn Sim, Diamond V; Zainah Zaid and Mohd Zaidy Abdul Rahman, Zaiyadal Aquaculture. Second row, from left, Ronnie Tan, Bryan Lee, QL Resources; Norman Lim, Cargill Digital Insights, Singapore, Fernando Castro Talero, Epicore BioNetworks, Vietnam; Fuci Guo, Fin & Shell Resources, Malaysia; Wan Nadhri Wan Fauzi, Blue Archipelago, Malaysia; and Serge Corneillie, Diamond V, Japan.

Hard Talk with young shrimp farmers

Second generation farmers from the right, Rizky Darmawan, Somthida Pakdeepak and Christopher Adrian Domingo Anglo

Three young farmers were invited for this year's ***Hard Talk with Young Shrimp Farmers*** for their diverse perspectives on managing farms. The farmers came from varied circumstances and educational backgrounds to provide their insights on keeping farms productive. The young farmers needed to deal with generational differences in opinion when implementing innovative protocols in their family-run farms.

Young farmers and their farms

In many regards, Generation-Y has been vilified as erratic, and at times inconsistent. These young, industrious shrimp farmers are in fact a dedicated lot, keen to learn, understand and implement new techniques in their businesses. Farm Manager of Aderma Farm in Cadiz City, Philippines, 33-year-old **Christopher Adrian Domingo Anglo** has been running its operations alongside his father and brother since 2015. The farm which started with monodon farming in the 1990s by his grandfather, shifted to vannamei shrimp production in 2015. Christopher Adrian has a degree in an unrelated field, Bachelor of Science in Business Management, but has managed the farm well enough to be awarded Charoen Pokphand (CP)'s 'Most Improved Farm in the New Customer Category' in 2015. His farm features best culture practices and uses CP's 3Cs culture technology (clean post larvae, clean pond and clean water).

Aderma Farm has 6 reservoir ponds and 24 culture ponds, each of 5,000-6,000m^2. Ponds are stocked at 100-120 post larvae (PL)/m^2. With partial harvests, shrimp survival rates range from 80%-100% with harvest sizes of 13-40g. The farm produced 400 tonnes in 2017. Generally, feed conversion ratio (FCR) range from 1.20 to 1.45.

As PT Delta Marine Indonesia's Director, 27-year-old **Rizky Darmawan** oversees the family farm in Sumbawa Island, West Nusa Tenggara, since graduating in 2014 with a Bachelor of Science in Aquatic and Fisheries Science from the University of Washington, USA. Keeping abreast of changes in the shrimp farming community, Rizky is an active member with Shrimp Club Indonesia, Head of the club's Sumbawa Chapter, and is the founder of the Young Shrimp Farmers Association (Petambak Muda Indonesia).

This 500 tonne/year farm in Sumbawa has 30 grow-out ponds, with sizes ranging from 3,300 - 5,000m^2, with 7 treatment ponds, and has plans for future expansion. The stocking density is 120-180 PL/m^2 with post larvae sizes ranging from 11 to 13mm. FCR fluctuates, depending on shrimp conditions. Rizky cited the special features at the farm: a >600 m inlet pipe into the ocean, waste settling ponds with mangroves at its end, laboratories for water quality and culture tanks for shrimp waste conversion.

Similarly, 23-year-old **Somthida Pakdeepak** began working on the family farm right out of Kasetsart University's Faculty of Fisheries Aquaculture in Thailand. The 35ha Ao Kho Farm in Chumphon Province, Thailand was founded in 1987 and originally farmed the black tiger shrimp. It shifted to farming vannamei shrimp in 2001. Somthida was appointed Assistant Farm Supervisor in 2017. Ao Kho Farm comprises eight culture ponds, two reservoir ponds, as well as treatment and settling ponds. Stocking density of PL12 ranges between 170 to 190 PL/m^2. Generally, survival rates are good, around 80% to 95%. A total of 250 tonnes were produced in 2017.

Traditional vs modern strategies

It is apparent that their main hurdle was changing the mindset of the older generation and instilling change.

"My father was very reluctant to change to farming the vannamei shrimp at that time because during the 1990s the black tiger shrimp industry was at its best, and then collapsed suddenly in the Philippines," said Christopher Adrian and it took some persuasion before they gave it a shot. "The difference between my father's and my time was not only the shrimp (black tiger versus vannamei) but also that with the black tiger, it was purely an export market. Today, we have both local and export markets with the vannamei shrimp. I convinced the first generation, especially right now that R&D is so vast, that we have to follow what is new to succeed because if we go back to the old ways, we are probably not going to make it again."

Sustainability

Rizky on the other hand finds a lack of interest on ecological farming practices among many of the earlier generations. "I think we (younger generations) are thinking more on sustainability. My parents did not see a need for settling ponds and preferred another culture pond. When they first built this farm, they had massive successes for 2 years and then it went downhill for a

couple of years. I started changing how they worked and right now the production is stabilising. We are profitable, and I think that's the most important thing about this business.

"So, one of the things I applied when I inherited the business was risk management," said Rizky on learning about the science behind shrimp farming and harvesting early where necessary to mitigate losses. He also elaborated on the mistakes he made at the beginning. "I started as a farm technician handling eight ponds. I tried to apply what I learnt in school and failed. I guess how you change the senior's mind is to slowly show that you can learn and little by little they will start to trust you."

Changing technology

Somthida's plans to involve her parents concentrated on three areas. "The first point was technical enhancement. Before I graduated, I shared ideas with my father on reducing the number of culture ponds and increasing focus in areas like water treatment and management. We could still maintain the production volume when compared to what we did previously with seven culture ponds," said Somthida. "Starting as farm technician responsible for water quality, feed and shrimp health management, I was learning real farming practices by doing, then implementing what I learnt from my university. I tried using a venturi aerator, an idea from other farms with excellent results."

She then leveraged on the advantages of studying in a local university by recruiting three former classmates as technicians managing two to three ponds each, to achieve consistency and efficiency. "When we decided to expand the culture areas with this model, we needed more technicians to operate the farm. My father agreed with this idea, even though it will be costly. Today, we have three technicians (excluding me) to manage eight ponds.

"My second venture was to find an alternative market. We previously sold our shrimp to local processing plants but during the crisis in the last 4 months, my mother and I searched for local buyers in Chumphon Province, offering fresher and cheaper shrimp as compared with those from middlemen," said Somthida. Cutting out middlemen from the equation, I gained USD 0.30/kg. With demand, we could partially remove biomass from shrimp ponds daily to allow the remaining shrimp to grow faster. We harvest 10g to 44g shrimp, with seven partial harvests over the crop cycle, and with good feed management, we get FCRs of 1.2-1.4. We increase production capacity and earn back part of our investment," added Somthida.

"Thirdly, was digitalising farm data. We began recording data using a Thai Government social media application Thailand 4.0 to get quick reports on emergency incidents and feeding status and share real-time information with others. Also, I am convinced that storing data online makes it easy to use, recheck, analyse and share."

Disease mitigation

While the first generation started with disease-free farming more than 30 years ago, these young shrimp farmers were dropped into the deep end, into shrimp farming beset with diseases. These three panellists then discussed their experience with diseases most likely to hit their respective countries, and their mitigation efforts.

"Diseases that have occurred in my country are the infamous ones – EHP *(Enterocytozoon hepatopenaei)*, early mortality syndrome (EMS) and the most prevalent, the white spot syndrome virus (WSSV). What we do to mitigate them is biosecurity," said Christopher Adrian. "At the end of the day, it is still people management – no matter what protocols we use; if you do not manage your people to follow the rules and regulations, you will be in big trouble. Our worst survival rate was 65% and that was due to staff issues."

"When I started back in June 2015, we got hit with WSSV once in December of 2015. Buyers stay at the perimeter of the farms and we use 10-12 hauliers to bring the shrimp to them."

Conversely, the worst disease to hit Indonesia is the white faeces disease (WFD). "I think because in the case of WFD, there is no immediate mass mortality. Instead there is chronic mortality, and shrimp are eating but not growing, costing farmers more than WSSV, because they do not know when to pull the plug. So, for me it is risk management. I wait for 1 week or 2 weeks to sample and keep monitoring problematic ponds, so I can make a decision on whether to harvest or not. Our survival rate drops to around 55% with diseases," said Rizky, "We check the daily feed intake. If the shrimp do not even feed that means that it is bad. Then, when the ADG (average daily growth) is 0.15g or less, we harvest. Rizky's message was to observe shrimp behaviour and not take a rash decision to harvest.

"What is the scariest disease in my life as a shrimp farmer? It is all diseases without a doubt," said Somthida. "I find that all diseases are big threats to me because once infected, it is sure to cause damage – increased FCR, lower survival rates, higher production cost or worse we could lose the entire crop," she said. "In my farm we have five criteria. Firstly healthy, disease-free larvae; secondly clean water, thirdly clean ponds, free from organic matter and contamination, fourthly management through scientific investigations, and lastly good team work. Each one of us is the keeper of success, and all of us have to commit and perform our jobs with a high degree of responsibility."

Wish list

As research and development is a key component in the sustainability of shrimp farming, the panellists were asked what areas of contribution they would gain most from – genetics, health management, or feed and processing.

"The thing I would like to see most is tips to farmers on how to improve the culture system. And also, hopefully in the future, improvement on the seed and fry quality for faster growth and immunity to diseases," said Christopher Adrian on his main priorities.

Rizky, however, focussed on robust genetics as diseases continue to evolve, as well as better waste treatment technology. He added that improving technology to keep shrimp fresh after harvest would also help.

Measuring all areas as equally important, Somthida believed a combined effort is the ultimate answer. "But if I must choose only one, I find shrimp genetics to be the most important factor because I cannot do it myself and yet it will give the most impact to my farm.

Despite rampant diseases and production challenges, the three young farmers nevertheless retain a hopeful outlook on the industry. To them, the continuous increasing demands on shrimp production and the time spent in research and development promote a bright future ahead for the industry.

REPORT ON BREAKOUT ROUNDTABLE SESSIONS

Review on current issues & develop proposals for change implementation & KPIs

CULTURE TECHNOLOGY AND INNOVATION

Estimation of biomass and carrying capacity
The general agreement is that there is no widely accepted computation. Most of the calculations are based on trial and error and practical experience rather than real scientific inputs.

With regards to **estimating biomass**, in Ecuador, this is based on three parameters: feed consumption, biomass estimate with weekly cast netting, and the human factor where the technician knows his ponds. The relationship between feed consumption and biomass is based on feeding tables, average growth and survival for each pond, as values can differ between ponds. The technician then calculates the average and uses this for monitoring. Computations on the estimation of biomass are also based on the gut feel of the technician, the actual consumption for the day and on the weight gain each week. Biomass is estimated to be 3100kg at any given time. In Thailand, the estimate on biomass is derived from record keeping. Farmers check feed trays which show the feed consumption and compare with the feeding table. The feed conversion ratio is used to match the total feed used, stocking density, size of shrimp and water quality. If ammonia is high, this is an indication of overfeeding. Gradually this is fine-tuned, year after year, crop after crop. Currently, farmers can tell if the size of shrimp is 100/kg and feed is 100kg, and the biomass is 10 tonnes/day.

Extra biomass in the pond occurs when some hatcheries give an extra 10 or 20% above the amount ordered. Equipment such as those used in the salmon industry to measure real biomass, in real-time for each cage was suggested. But at the moment, there are too many variables in methods and pond sizes and it is very difficult to have actual numbers.

Carrying capacity can be calculated based on feed efficiency criteria. Feed index, specific to Indonesia, was explained as the expected ADG from the next sampling. For example, if using a 0.6 feed index, and the sampling showed an ADG of 0.3g or 0.4g, this indicates that more feed was being added to the feed tray, but the shrimp were not growing. This implies that something is wrong within the pond – possibly due to overpopulation or to a disease problem. An equation is used for calculating the feed index.

Carrying capacity should also be a function of the profit margin. It is important to know the break-even production in the culture facility. However, in the example in India, if 50% of the farms are operating at any one time, this will create less pressure on the ecosystem and the carrying capacity. Controlling discharge can increase the carrying capacity.

Some data on carrying capacity were provided.

- In Vietnam, carrying capacity ranges from 0.7 to 0.8 tonnes/ha for semi-intensive ponds and 10 tonnes/ha for lined ponds with central siphons.
- In Thailand's closed system, with no water exchange but only with top-up water, the carrying capacity is 9 to 12.5 tonnes/ha.
- For recirculating systems in Vietnam called IAS or greenhouse, it can go up to 5kg/m3 (about 50 tonnes/ha).
- In the Philippines, the average carrying capacity is is 15 tonnes/ha, but with partial harvest, it can go up to 30 tonnes/ha.

The group recommended that farmers be educated on using cubic metres (m3) rather than square metres (m2) to reflect the actual density and biomass and for more accurate estimation of the results. Today, pond depth is not limited to 1m but to 1.5m, etc. There is a need to record historical data in each farm.

KPIs on carrying capacity can be specific to each farm. Carrying capacity can be increased with investments, more paddle wheel aeration, liners, etc. Probiotics, better management and more skilful technicians can influence carrying capacity. The group listed some KPIs. The discussion focussed on the minimum dissolved oxygen (DO) of 4ppm.

The comments were that, in Ecuador, at less than 3ppm, shrimp do not feed; and the target is having DO higher than 3ppm. However, in Ecuador, working in an environment with exposure to stress factors such as pathogens, low oxygen and low temperature, can make it difficult to reach the genetic potential of the stock available. Similarly, whether with new improved genetics, this KPI is still valid. When vannamei shrimp first came to Thailand, 4ppm was sufficient, but as the genetics changed in 2010, the demand for DO was 5ppm, as at 4ppm, there were problems with growth. Growth was better with fewer problems when DO was higher at 5.8 or 6ppm. As performance of stocks is being genetically improved continuously, it requires continuous adjustment or management and higher oxygen levels. High oxygen levels are required to make the new genetics work.

A recommendation was to return to basic calculations, basically to estimate shrimp population and to carry out size sampling to determine the survival rate and what kind of feed demand on a specific day. Day-to-day manual monitoring of the DO, pH and salinity in a pond was also suggested. Carrying capacity varies with farming intensity: intensive farming, semi-intensive or super-intensive.

Automation and real-time monitoring
The general opinion was that many farmers may find automation too complex and are confused with several alarms being activated at the same time. The suggestion is for suppliers to invest in training and education to build up farmer skills; just as they are not afraid of iPhones or iPads, they should not be afraid of digitalisation. Suppliers should invest in education and training as well as develop more user-friendly machines.

The discussion was also on the cost of automation and its cost relative to human labour. Prototype machines are expensive although it is expected that with demand, costs will come down. The implementation strategy is for farmer associations to work with the companies and also with the authorities and government agencies, to promote automation.

More automation actually leads to the use of less human labour. One suggestion was semi-automation to overcome problems with the labour unions, and to have some control in the field. An example given was detection on feeding with the AQ1 systems. This auto-feeder does not provide timed feeding but is based on feeding sounds. However, in shrimp farming, with a lot of noise in the pond – the paddle-wheel noise, the wind noise, the rain noise – the machines pick up all the extraneous noises as shrimp consume feed. The group recommended the installation of sensors in ponds – submersible monitors, submersible probes or submersible cameras to monitor shrimp activity. Farmers can then use the equipment as a benchmark to monitor the rest of the ponds' performances.

Despite the above, automation and digitalisation are the way forward. Automation has become very necessary and as traceability comes to Asia, water quality data are getting

validated by certifying companies. The triangulation of data is very important now. Having automation without manual labour will really help to have real-time data and also help in traceability and certification.

Market-led production

There were several observations on market-led production. The first is the lack of information on the market: product quality, standard demand as different countries may have different demands on the size and also on cooking methods (head on head off, etc.), seasonal demand, and lastly, farmgate prices.

With regards to KPIs, this lack of information requires more networking and information sharing. Improving farm gate prices is by encouraging domestic shrimp consumption. The suggestion was a platform to pool pricing and production data to have a better control of pricing and of production (without having all the shrimp made available for the market at the same time but rather released slowly) to stabilise prices. Value-added or specialised products, for niche markets such as halal products for Muslims, organic products for the health-conscious, etc. were proposed.

All stakeholders of the shrimp industry: hatcheries, feed mills, packers and buyers, including middlemen should collaborate. Farmers should learn to communicate more with processors to better understand demand (size, etc.). Certifications like BAP or ASC can increase market access although these costs money.Another recommendation is for small farmers to switch to different species for niche markets. Examples are Brunei to farm *P. stylirostris* and India to farm *P. indicus* or *P. merguensis*. In some niche markets, there is a preference for the so-called 'wild shrimp' even though they are farmed. Certifications may open markets but should be made more affordable so that smaller farms can be certified.

Discussion with inputs from the floor included traceability. Feed traceability is already practised in Thailand. Complete traceability is possible for organic certification, tracking the animal from broodstock to the packing plant, and from farm to the importer in Europe or US. Certification is also possible, but the company needs to be sure that it wants to be certified as the cost of certification could be high and they would want to recoup this cost. At the end of the day, you need to know which certificate is good for a specific market.

There is a requirement to use feed certified to the same standard as that of a certification organisation for a shrimp product, or to use feed which complies with the same standards. In India, moving forward, the processors buying the product need a supplier declaration on the source of the product and all the other required declarations on the source of feed, post larvae and also the use of antibiotics. For BAP certifications, farmers could enrol for group certification under a processor who will register farms under the umbrella and cover the cost of certification. Thus, there is no liability to the farmer, provided they want to work longterm with the processor.

On the proposal to use the savvy block-chain technology to address traceability, the opinions expressed were that it is a little bit too early but will become increasingly important in the near future. Traceability is certainly a big issue, but the way that fish and shrimp is being dealt with globally is complicated. Block-chain is a tool just as there are other tools available in the market that can be used to make shrimp more traceable. The panel was informed that from January 2019, the Seafood Import Monitoring Program will be implemented by USFD. This then necessitates a complete traceability in farm production, and may emerge as a dedicated or restricted portal, which could in the future to develop into a block-chain technology.

FEEDS, HEALTH & ENVIRONMENT

On **tailor-made feeds** to serve genetic design, the group noted that each genetic design would obviously need specific feed quality to enable the animal to reach its full genetic potential.

Nutrient specification should be specified by the genetic provider, i.e. the provider of the new genetic strain should tell the industry exactly how to feed that stock. This follows the example of the broiler industry where the main poultry breeders (e.g. Ross breeders) can tell exactly, for every week of growth, the amino acid profile to feed their stock. This is something the shrimp farming industry should strive for.

There is a need to develop nutrient-dense diets as well as those with high digestibility by using pre-treated raw materials such as through hydrolysis. Since heat during feed processing may destroy enzymes added directly in the feed mixture, pre-treatment of raw materials with enzymes prior to putting them into the feed was suggested.

Two KPIs were presented. Firstly, the drive to achieve the maximum growth potential of the animal as determined by the breeding company. This goes back to putting pressure on the breeding companies to tell industry exactly how to feed their stock. Secondly, the establishment of a global shrimp association like the highly developed world poultry association for the global poultry industry.

Reducing feed waste, auto-feeders and extrusion

Does feed management cover all these – art, science and understanding shrimp behaviour? The strong message was that feed management is not pure science, but it has a fair amount of art involved. As mentioned by some speakers, "the shrimp farmer has to have a good feel; he needs to watch and understand shrimp behaviour when feeding, and look at feed trays." He also needs to build up a history to really understand what is happening in the ponds and try to estimate the biomass and other factors. The conclusion was that feed management is "not pure science but very much an art."

Auto-feeders will give a more targeted protocol on shrimp feeding and improve feed management. Sometimes, over or under feeding occurs, probably due to problems with the timer, etc. The recommendation is that more R&D, information and guidance are required. The group questioned whether **extruded feeds** are better than pelleted feeds or if this is just a perception. Is the additional cost to produce an extruded feed justified? More R&D is required to provide answers.

With regards to coating feed materials to prevent leaching, the industry should refer to pharmaceutical industries which have a lot of technology on slow-release and coating methods. On the art of growing shrimp, many questioned whether pond managers are sufficiently trained to manage their ponds.

Improving feed digestibility is a prerogative for all cultured species. The industry needs heat stable enzymes, which can go through the processing of shrimp feed. It also needs to look at alternatives: enzyme coating technology or post-pellet additions. Pellet lines are often very small so adding a PPLA (post-pellet liquid application) system to a small pellet line is just not financially viable. Low-temperature processing techniques were discussed as well as ways to achieve the same pellet feed quality with lower temperatures.

Information on the digestive system of the shrimp (such as the pH values for an enzyme to function in shrimp and effective delivery of enzymes for the shrimp) is lacking. Sometimes, within a large company covering animal nutrition, the size of the shrimp

industry does not justify the research development for specific enzymes.

The determination of BOD (biochemical oxygen demand) and COD (chemical oxygen demand) soluble nitrogen is an important **KPI** to monitor leaching of these important nutrients into the water. Feed performance and feed efficiency are standard parameters in the industry.

Functional feeds: overcoming trust deficits of farmers
There are functional feeds in the market place but there is a degree of uncertainty in their efficacy. Evidently, there is a lack of trust; shrimp farmers do not believe that they gain the benefit tied to the extra cost of these functional feeds.

It was difficult to determine whether one functional feed would work across all farms because each farm may have different requirements. It is essential to fix the fundamentals; good culture conditions must be given priority before considerations are given to the use of functional feeds. There are doubts on whether functional feeds can work in the present culture conditions where animals are stressed daily with low dissolved oxygen and the immune system is compromised.

Today, some specific targets for functional feeds in shrimp farming include disease prevention, immune stimulation, gut health and moulting. Aside from the extra costs, there are other concerns on the farmer's side, such as:

- Lack of specific targeted response for a functional feed in addressing a certain state of the animal
- Mode of action of a functional feed and what are the quantifiable benefits
- Knowledge on what they should measure and what are the gains from doing this
- Each farm is different and functional feeds should be catered to specific needs

Among the **KPIs** suggested is a need for a more efficient way to measure the efficacy of functional feeds, including determination of lymphocytes, phagocytosis, reduction in measurable stress response, heat shock proteins (HSP), improvement in survival rate, improvement in defence against disease, monitoring of anti-microbial peptide synthesis levels and improved efficiency of the shrimp digestive system.

Building trust with farmers
Trust by the farmer means equating performance with feed value. It is also about science - being able to measure these results at the farm level and educating farmers on what to expect and how to measure them. Functional diets are poorly understood; it is not about treatment but about prevention. An example given was that during discussions on functional diets, results and outcomes, farmers asked, "Can they treat EMS or white spot syndrome virus (WSSV)?"

The issue is how to move from treatment to prevention. Prevention is risk management. Functional feeds are working well in salmon farming but why is it so difficult to work in shrimp farming? Over the two days, it was often reiterated that the shrimp farming industry will be considered a success when there is a shift from treatment to risk management and prevention.

Often the word "solution" was being thrown around too easily. Taking the example from internal R&D, in the fish industry, a functional feed is a tool in the toolbox for prevention and is part of the health management strategy of the farmer. It comes with high quality science, documenting every level, not just in the laboratory but in the field as well. With these in place, the farmer and the stakeholder will have trust in what is being provided.

How do farmers view functional feeds?
There were two inputs. In Indonesia, a farmer said that he would pay and use functional feeds provided they work (i.e. not empty promises). It works when within a cycle, the feed was proven to stop a disease (e.g. white faeces disease-WFD). However, if the feed can improve survival by 5% or 10%, it could be due to several factors. This means it will be difficult to prove that the improvement was due to the functional feed for which he paid a 30% premium. Mistrust happens when farmers pay for empty promises.

In Thailand, shrimp farmers are already using higher priced feeds for the nursery stage, some with functional properties. Farmers willingly pay more for special feeds when they are convinced that they will get better production.

Farm trials were suggested as results from laboratories cannot always be extrapolated to the farm. However, even at the farm level, proving the efficacy of functional feeds is not so simple as the dynamics of each pond is different. Changes with the weather, environment and water quality will influence results. Even with a few control ponds, it is actually very difficult to determine if the functional feed works.

The farmer needs assurance that the functional feeds work. To decide on the best feed to use, a farmer tests various feeds in cages and then selects the best. He also conducts commercial grow out trials and does the economic analysis to determine which feed gives the best results.

Today, top dressing of feeds is not well-controlled. Addition of functional ingredients or additives should be done at the feed mill based on the requirement or request of the customer. Therefore, with requests, should the feed miller absorb the cost of adding a functional ingredient into feed or should he pass it on to the farmer?

Situations with top dressing and costs were presented:

- In Thailand, there is the occasional top dressing of feeds by the farmer, such as with probiotics. Shrimp farmers seek better feeds and are open to feed millers adding functional ingredients at the feed mill and are willing to share costs.
- In India, there may be no interest among farmers for factory-added functional feed unless the feed mill comes forward with trials and demonstrates a quantifiable benefit of such feeds. The farmer will top dress feeds with probiotics which may be bought from a feed miller or from other sources. Even if the feed miller has a feed containing probiotics, often the farmer will not believe that the feed contains a probiotic or any other functional ingredient.
- In Indonesia, farmers top dress ingredients/additives in the farm because small farmers cannot meet the minimum tonnage required by feed millers to add onto the feeds. Secondly, it is cheaper for the farmer to buy the ingredient to top dress, rather than for the feed miller to include the functional ingredient into the basic feed. If the feed mill does not charge too much, a win-win solution may result for both parties.

Sharing costs
Farmers do not wish to pay the premium for functional feeds without knowing the outcome of use, even though feed millers are transparent on the functional ingredients of their feeds. On sharing costs, a proposal is to have a profit-sharing pricing model between the feed mill and farmer. The farmer will share the increase in production output cost (such as five cents/kg) because there is an improvement. However, the question was how to determine that improvement?

In Europe, BioMar had offered the 'No cure, no pay' deal in order to introduce new products. The main concern is dealing with situations where there are many different variables in the environment. The feed miller also needs to be confident that the farm is well-managed for a good and decent trial.

Another option suggested was that if the feed product can clearly improve survival (say 5%) it will mean that the feed miller can sell 7.5% more feed. The feed mill may not even ask the farm to pay for the cost of this additional ingredient since it can benefit from higher sales.

Perspectives from feedmillers
Feed millers regard farmers as the entrepreneurs who at the end of the day must make a profit from their production. A feedmiller sees functional feeds as an opportunity to market special feeds for special needs. There is a big need for these speciality feeds to be supplied to the farm and the farmer should not be left to juggle around with additives at the farm level with a lot of leaching in the water. Sometimes, there is an overdosing when the functional ingredient/additive works very well.

For the feedmiller, a request to add vitamins (such as C and E) is not difficult as the feedmiller has these ingredients in the factory. Additions such as to 200ppm level simply mean an extra cost for the feed. But from the factory's point of view, there must be a minimum volume of feed such as 30-50 tonnes to do this run. Factories with HACCP certification will need to document the addition of this additive/micro ingredient.

In Thailand, some super-intensive shrimp farms demand functional feeds, and most of the feed companies, as volumes tend to be quite large, have been happy to supply such feeds, usually on a cost-plus basis. When customers are successful with these feeds, they will continue to buy them.

There are cost increases when adding ingredients such as organic acids as this will require special equipment. To do it right, adding probiotics requires quite large investments for a feed company. The production of salmon feeds with probiotics has been costly. Another challenge is that when a farmer requests to add on an 'untested ingredient with doubtful properties, as the feed supplier, the feedmiller is responsible for the feed and if there is a problem, it becomes that of the feedmiller. There are also food safety and environmental considerations. Ultimately, the feedmiller needs to document what is being added and just cannot add on any ingredient/additive.

Prior to the incorporation of a functional ingredient, an Indian feed producer seeks enough data from suppliers on the functional ingredient. These are not laboratory data but efficacy trial data for the specific market such as in India.

Feedmillers also convince themselves by running trials before marketing to farmers. The feedmillers want the farmers to understand the process undertaken by them before introducing any functional ingredient. They also want to explain the scientific rationale. This is a new trend and moving forward, there will be more interaction with farmers.

Feedmillers have constraints in meeting specific demands of shrimp farmers. Large feedmillers have volume constraints in producing functional feeds. Most of the time, the volume does not justify the production of a specific functional feed. Small feedmillers can find a niche market with functional feeds by providing such services to farmers.

Documentation
In Europe, there are functional feeds for the salmon feeds and the salmon farmers are willing to pay for the extra cost. This comes with full documentation. Probably in the salmon industry, it has been easier to prove that the functional feeds work because there are less variables than in shrimp farming. Success in shrimp farming is very dependent on the environment. Over time, it is also possible to have documentation for the different farming conditions. Adding details on the label is a legal requirement in Europe and it is well known that BioMar has Bactocell in its feeds.

An example in Asia is the recent launch of a functional shrimp feed in India where the label clearly indicated an extruded feed with the functional additives used. Confidence in the feed came from two years of a successful market introduction. The feed price is 30% higher than regular feeds. This could be the beginning of a new trend and for others to follow.

Similar to most countries in Asia, feed labels only indicate proximate composition of feeds. If adding information of the functional ingredient/additive is required, the Department of Fisheries (DOF) Thailand will comply if there is good rationale to do so. DOF agrees to the use of functional feeds, but proper feed management is more important.

There were different views from two feed millers:

- Feedmillers have the responsibility to be honest with farmers. Indicating the functional additive information on the feed bag is possible provided that the brand or supplier is not revealed. An example is phytase. At the end of the day, the farmer will make choices depending on the results and the best return of their investment.
- It is in the commercial interest of every feedmill to show the distinct difference between its feed and that of its competitors. Only generic information is provided on labels. There must be trust between feedmillers and their customers, and farmers will have faith in their feed millers when told that a functional ingredient is in a feed. The functional ingredient will remain a commercial or trade secret but in an indirect way, the components of the functional ingredient can be revealed to clients.

Earning trust
In Indonesia, this issue of using functional feeds can be quite complicated on the part of the feedmiller when functional feeds are proposed to overcome *Enterocytozoon hepatopenaei* (EHP) or WFD. The feedmiller would have produced and registered the feed. The reputation of the feedmiller is at stake when the feed does not work. The preference is to have a premium feed with additives, sold at a premium price, and an economical feed. It will be easier to explain to customers that the premium feeds include additives while the economical feeds do not.

A model to emulate was presented by John Tinsley, Biomar, Costa Rica on the acceptance of functional feeds in the industry in the Americas. An important feature is the work of the technical team post-sale. The company recognises the cost for the customer as well as its own investment in R&D. It is not just providing a feed bag but to make sure technicians work with industry to get the best out of the feed. There are analyses on various parameters to show industry that the functional feed provides good results. Technicians need to work hard with customers to document how such feeds work.

GENETICS, HATCHERY & NURSERY

On **desired traits**, fast growth has been successful. Selection for specific environments or specific country requirements (salinity, density, etc.) was considered important to meet the demands of customers in a particular country or market. Robustness as detailed above was preferred over resistance by the group. Today, the push to develop specific resistance is less than before. This is because after considerable time and effort were taken to develop resistance to a specific pathogen, a new pathogen comes along and it is back to square one. Selection for reproduction without ablation was considered important in some key markets in Europe and the U.S.

Immune priming was explained as tuning to exposure to different or many pathogens rather than to specific pathogens. To date, the selection is for viral challenges and the question was whether it can be done, to have shrimp withstand a particular bacterium (e.g. toxins for AHPND-acute hepatopancreatic necrosis disease). However, immune priming is a fairly new concept and there is a need to develop new methodologies to measure progress and heritability (with or without exposure).

The group noted that some traits may be very interesting for markets but heritability and diversity for selection are not known. With high heritability, improved stocks can be quickly developed. Conversely, it may be difficult if heritability is very low or non-existent. Any time, a trait or a combination of traits is/are identified, programs work on the genetics, identifying the heritability and diversity to determine if these are really practical or realistic goals for genetics. The future considerations may hinge on a balanced selection among the following parameters: growth, fitness, robustness or disease resistance or selection for several traits rather than only for fast growth.

Among the **KPIs** proposed, robustness as an indicator is vague, as it be several parameters ranging from survival of stress tests/challenge, to pond yield (survival X growth). In the case of resistance, some programs look at survival from specific disease challenges with white spot virus, Taura syndrome virus, or different viral challenges or using the AHPND challenge to identify families which cope better.

The vannamei shrimp target is a challenge. Based on the experience by a group member, monodon broodstock from a selection program gave a much lower nauplii/female compared to a same size wild brood stock. This shows that industry has a long way to go before domesticated broodstock can achieve the same fecundity as wild broodstock.

In the discussion on **management of programs** and **genetics**, an important area is pedigree and genetics information: how the program is run and selection of families is done. There is now a situation in China where a significant part of the market uses F1 genetics or first generation genetics (from a genetics program from outside China) to grow this first generation as broodstock and sell the second generation post larvae (called F2 genetics).

Since genetic companies do not supply every single family each time to a market and the number of families that can be built from a single batch of F1 brood stock is very limited, the consequence is very quick in-breeding. Not only does this affect farm performance but genetic companies may lose interest in developing genetic programs for the Asian market.

Although SPF (specific pathogen free), SPR (specific pathogen resistant) or SPT (specific pathogen tolerant) have been well defined by the Oceanic Institute, Hawaii several years ago, there is still a lot of confusion on the meaning of these terms. The group reiterated that the term "specific pathogen" is meaningless unless the specific pathogens are identified. For example, vannamei is SPF for monodon baculovirus. Resistance or tolerance would also need to be supported by test results and freedom - PCR test results to demonstrate freedom, disease challenges to demonstrate clear resistance versus a naive population.

Hatchery

With **broodstock**, use of fresh and live feeds, particularly for maturation, remains a major biosecurity risk. A large number of diseases are spread by shipping of live polychaetes around the region. Unfortunately, governments monitor movements of live shrimp with SPF status between countries in the region or across the world, but there is very little enforcement or interest on applying the same rules to live feeds which have been implicated in the transmission of AHPND and IMNV (infectious myonecrosis virus). It is a major blind spot, allowing movement of live feeds around different countries without the same controls applied for SPF shrimp.

Treatment from freezing to pasteurisation to cooking can remove AHPND, but there is resistance as hatcheries believe live polychaetes are more effective and treated polychaetes reduce fecundity slightly. Industry needs to relook at the current approach on the use of live feeds in hatcheries when working on a breeding program where one mistake can basically ruin millions of dollars of investment.

Polychaetes affect the quality of production but industry is unclear on their essentiality. Their absence in a maturation diet, decreases nauplii production by 20 to 30% or higher. In Asia, hatcheries use different species with different nutritional qualities; identifying the best is an issue. Perhaps Asia could use cold water polychaetes but then little is known on their nutritional quality and components (prostaglandins and hormones). There are SPF polychaetes being produced in different countries but little is known on how the SPF status is maintained, identified and certified.

There is renewed interest on replacing fresh and live feeds with commercial diets. The group noted that knowledge on broodstock nutrition has not improved since the 1990s. Successful production of broodstock diets which will maintain the fecundity and quality of the nauplii, will require focus on broodstock nutrition. This is a specialised activity as the market (by volume) for a feed company may be relatively small. Going forward, commercial diets are required to have better predictability, consistency and reduced biosecurity risk in the hatchery.

Nutrition is very important for better PL quality and there is interest to change to more off-the-shelf solutions; relying less on live feeds, to reduce disease risk. By reducing the production of artemia and algae, hatcheries can reduce biosecurity risks. In Thailand, hatcheries now depend on outside sources of live or chilled artemia supplied daily or every two days. The flexibility is that hatcheries can order it whenever it needs. Artemia use differs between countries/region. The question asked is: should hatcheries use more artemia or use the same amount with different feeding regimes to produce good quality PL? Similar to artemia, algae culture is not cheap and you have to have dedicated algae production facilities.

What makes good **PL quality**? For the farmer, it is the quality that will give him good farm performance. For the hatchery, it is the effectiveness of the production process to produce healthy and fit PL. Secondly, it is to provide a good quality product to customers. One important criterion is low size variation.

One major KPI is a coefficient of variation (CV) of less than 10%. This is simple to manage below a certain size but once above PL12, the CV becomes much more widely distributed. Hatcheries have two approaches when CV is high: select larger PL to reduce the CV or give a higher percentage of free PL to the customer. But the group asked whether CV is really important as almost all farmers will not calculate the CV (the standard deviation of 100PL by weight or length). Farmers eyeball PL in a bowl and estimate the proportion of the larger PLs. It is a subjective test rather than an objective test. A hatchery would use CV to identify their performance.

For many years, rostral spines have been an indicator of age. The group said that what is important is the number of days taken for the larvae to reach the PL stage and the physiological development of the PL will change depending on the temperature, feeds, etc. A PL15 could have a totally different size and gill and rostral development. Independent measurements such as rostral spines, gill development (full and partial), ability to withstand stress test and PL length is independent of the duration taken to attain PL stage. The information with stress tests is that if PL do not pass a stress test, they may pass a repeat test after 2 days which indicate that they are physiologically developed.

Tank survival may be useful in determining PL quality but often farmers do not really know the survival rate of PL in the tank that he is buying from. However, this may be different if the farmers have a very close relationship with the hatchery and look at the tank they are going to buy ahead of time.

On measuring bacterial loads – total load and *vibrio* counts, the point raised was that the numbers suggested for yellow and green colonies seem to be high compared to in the past. These

are levels which are not considered a challenge. Can *vibrio* be eliminated from the PL being sold? The response was this is a tall order but it would be useful if hatcheries can manage with having a very low *vibrio* load.

On PCR testing for SPF, white spot syndrome virus (WSSV), EHP *(Enterocytozoon hepatopenaei)*, AHPND, IHNV *(infectious hematopoietic necrosis virus)*, it is noted that the Asian pathogen list is different from the OIE list. Nevertheless, it is important to specify the pathogens in question. The sample size is important. If the PL is small, the result can be negative although the prevalence of a particular disease in the tank is high. The emphasis is to use 15 PL, which will pick up a 95% confidence of picking up a 2% prevalence in a tank which may be too high for some diseases. To declare that a batch of PL is free of disease, there should be a declaration that it is disease-free based on SPF history, or it is below a particular threshold based on the sample size taken and tests carried out.

A measure of lipid content of the hepatopancreas can show that the shrimp is not only eating, but is digesting food well and is healthy. Today, this is qualitative only. The checks are on the lipid vacuoles; microscopic checks detect the proportion of PL with deformities.

Muscle gut ratio is very often used instead of measuring the muscle and gut size. The suggestion was to look at the presence of muscle mass or how much muscle occupies the last segment. About 75% or more indicates good quality PL.

Growth also determines PL size: either the length or the weight after 'X' amount of days, to ensure that the growth rate in the hatchery is good. The sum of observations for a good rate in the hatchery will give a good growth rate in the farm.

On in-house versus third-party testing, the comment was that if a hatchery does all the tests, whether the customer trusts the results or not depends on the trustworthiness or the relationship between the hatchery and customer. In the Philippines, a number of different bodies do third-party testing for the farmer before the purchase of the post larvae. In the end, the customer decides. Whichever method is used, buyers need to be aware and pass the farmers' own internal tests.

There are three major **health issues**; *Vibrio*, Zoea-2 syndrome and luminous bacteria. *Vibrio* is related to luminescence because of *Vibrio* harveyi. The rampant use of antibiotics in hatcheries may cause rapid build-up of resistance. Zoea-2 Syndrome remains a problem in some areas. The group stressed on the importance of algae quality produced in the hatchery. Early nutrition is critical. The focus of the nauplii's energy store is to make sure that the nauplii develop into good zoea-1 and then complete metamorphosis or growth into zoea-2 and subsequently, through to zoea-3 into the mysis stage. More work is required here. Luminous bacteria are seasonal and there are huge amounts in the source water. Water quality and how water is treated must be given utmost consideration.

There is a better chance of success with **probiotics** in hatchery as compared to ponds because the former can start with a very clean water source. An interesting approach by Dr Loc Huu Tran, ShrimpVet Laboratory, Vietnam is to use probiotics as pre-treatment before stocking nauplii. The suggestion was to prepare the water with probiotics, and then stock nauplii, instead of just stocking nauplii in and adding probiotics later. The use of probiotics must be given careful thought; the farmer needs to be specific on the type of probiotics to use and for what purpose.

There was a lot of discussion on the best methods for **water treatment** such as the use of ozone versus chlorine. Both fulfil the same purpose. There is now more knowledge around the chemistry of chlorine use and how to use chlorine effectively. Some hatcheries may be very successful with the use of ozone. Robins McIntosh, CPF, Thailand had commented that with chlorination in a hatchery tank followed by stocking of nauplii, a few weak nauplii may be swimming around a day later as basically there is a monoculture of bad bacteria. Chlorination and preseeding with a good probiotic could be the best approach.

The group deliberated on the **pricing structure of PL** and a fair price base for post larvae (PL) to reflect cost of production and the genetic improvement work. The amount of investment in genetically improved post larvae is high. However, it is also about prices farmers are willing to pay. PL producers should be rewarded for better performing PL.

On what is a **reasonable mortality allowance** of PL, the example given was: if PL in Thailand cost 12 Thai satang/ PL, with a 20% extra allowance, the actual price is reduced to 10 satang/PL. In addition, mortality allowance expectation has gone up; it used to be 10%. PL performance can be measured by yield index – where a million PL should produce an estimated 20 tonnes of shrimp, and a very good performance will be up to 30 tonnes/million PL.

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