

# AQUA CULTURE

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World of Artemia Cysts

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A New Normal for the Philippines Shrimp Industry

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Methanotroph Bacteria Protein Meal

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Off-Season Spawning of Milkfish

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# Recovery for Asian Shrimp in 2021



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*Greenhouse super intensive shrimp farming in the Philippines. Picture by Dr Prakan Chiarakhongman, Charoen Pokphand Group Global, p46.*

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A hybrid TIFSS and Second Marine Aquaculture Technology Forum



Zuridah Merican

## Forecast and view for 2022

Ecuador, who is leading Latam's growth done right? Ecuador has positioned its shrimp very well with its Sustainable Shrimp Partnership program. We might say that Ecuador is a single country, but we have yet to see the marketing strategy of sustainable shrimp from any single Asian country. Crossing the one million tonnes benchmark means nothing if one must sell it at the lowest price.

EU in terms of seafood imports. Due to supply chain disruptions leading to a low inventory of imported seafood in China, local production of seafood has picked up to meet demand. Whether this is a temporary trend remains to be seen. The recent supply chain disruptions have highlighted again the importance of food security but on the other side of the coin, it also provides the opportunity to produce local, sell local.

This is AAP's view on the direction of the industry and how we can take advantage of the situation.

1. The end of the editorial in issue Nov/Dec 2021 mentioned 'anticipate the rebound' and this was also the view of Seafoodsource's Cliff White where 'the seafood industry is at the cusp of a renaissance'. The lockdown from 2020 encouraged consumers to cook seafood at home leading to a 35% and 25% increase in retail frozen and fresh seafood sales, respectively. When restaurants in the US re-opened in 2021, seafood came out the winner as we see shrimp imports top a million tonnes for the first time (Rabobank) and Norwegian salmon exports hit a new record. This gives the aquaculture industry a strong tailwind.
2. While shrimp production showed compensatory growth in 2021, Asia is losing out to Latin America (Latam). In 2008, Asia had 82% market share vs Latam at 13%. Fast forward to 2021, the ratio is now 63% vs 27%, said Robins McIntosh at TARS 2021, and the forecast in 2030 is for 55% vs 35%. What has
3. Mainly due to disease issues, shrimp farmers in Asia are facing headwinds with rising cost of production. 2021 saw all countries raise shrimp feed prices due to increases in feed ingredient prices. If Asia is unable to improve from an average survival rate of 60%, the industry may see increases in production cost/kg from USD3.50 to USD4.00 for size 60 shrimp. Margins will be squeezed. If additional lockdowns or new SOPs reduce the buying capability of processing plants, ex-farm prices will drop. The warning signs are here already.
4. Consumers are looking for seafood alternatives and the seafood retail market expansion provides a huge opportunity for Asian marine fish. This should provide the catalyst for Asian seabass (barramundi) and snappers. However, this sector lacks the economies of scale and integration and all it has to do is look at the salmon model. Asian seabass has improved in the value chain segments of farming and feed, but it still lacks in genetics, processing and marketing.
5. Both pangasius and tilapia are more dependant on the retail segment compared to the food service, so both species did not suffer as much during the lockdowns. However, the increase in feed ingredient prices has had a more profound effect on feed prices which in turn will require higher ex-farm prices, otherwise will farmers temporarily exit the business?
6. Although one does not have accurate data on seafood consumption, China can easily punch among the heavyweight markets of the US and
7. Today's supply chain disruptions highlight two major issues. The industry forecast is for shipping to start normalising from mid-2022. However, port congestion and clearing may take a longer time which will also have a knock-on effect on the number of containers 'trapped' and waiting for turn-around. Clearing seafood containers at China's main ports has the additional hurdle of Covid-19 inspection on the packaging and the industry hopes that this will not become a norm for any other importing country.
8. Asia is still lacking when it comes to innovations in branding and marketing. With SDGs, markets are looking at carbon footprints and life-cycle assessment of seafood products. There has been talk of climate-friendly seafood, but will an Asian producing country be able to take advantage of this?

***Ironically, the pandemic has reset the playing field for all stakeholders in the industry but in the multispecies aquaculture industry, each species has been dealt a different set of cards. Each country should pivot according to the country – species combination of circumstances.***

If you have any comments,  
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## Reviews in 2021

Some clips on significant events shaping Asian aquaculture and newsmakers in 2021

### Global supply and demand do not determine price. Supply chain does

farm

processing

Container, shipping  
& port congestion

In-country inventory

During the lockdown in 2020, consumers have learnt to cook seafood at home, thus increasing sales in the retail sector. In 2021, vaccination and revenge dining have seen a rebound in the food service sector, leading to a net increase overall. While this demand has led to a price increase in the consumer markets, this has not translated to higher ex-farm prices for farmers. Why the mismatch?

The above chart describes the supply chain for aquaculture exports. A lockdown SOP in a producing country like Vietnam in July 2021 mandated processing plant workers to 'eat, sleep and work' in the factory, resulting in reduced overall capacity and buying capability, and therefore, lower ex-farm prices. Meanwhile, container freight charges to the US have increased more than five-fold due to fewer vessels plying and the lack of containers. The situation was exacerbated by port congestion at Los Angeles (LA). It was reported in The New York Times that more than 273 container vessels were anchored off LA port in mid-October and if these containers were lined-up end to end, it would reach Chicago from LA. These containers are essentially 'trapped' or temporarily out of circulation.

In China, inspection for Covid-19 on seafood packaging has contributed to port congestions and clearing a seafood container has risen from 5 days pre-pandemic to 4 weeks today.

In February 2021, markets turned sharply upward, and everyone wanted products and services immediately. US port volumes were up 43% due to increased consumer demand. Logistics were a mess due to Covid-19 SOPs with a shortage of port labour, warehouse labour, train capacity, truck capacity and chassis, noted HJ O'Neil Commodity Consulting, at the USGC Aqua Talks in November. Although every container vessel is back in service today, there are acute shortages in the supporting supply chain, and shipping companies cannot afford to have empty containers for 45 days going in the opposite direction (i.e. from US to Asia).

Fewer ships, container shortage, and port congestion have led to low in-country inventory for seafood thus sending prices upwards. US fresh, frozen and shelf-stable seafood prices have all shot up 8-9.2% in 2Q 2021 vs 2Q 2019 (Seafoodsource.com).

### Rising feed ingredient and feed costs

Between August 2020 and August 2021, soybean and corn prices have climbed 60% and 74%, respectively. In October 2021, the Bloomberg Commodities index (BCOM) was at a 10-year high. These high protein meal costs have put pressure on feed prices. A typical shrimp feed grower diet of 36% crude protein in Asia has been priced at USD1.10 per kg without any fluctuation over the past decade but shrimp feed producers across Asia have been forced to increase their prices by up to 10% in 2021. Soybean prices have a bigger impact on pangasius feed where previously a typical diet of 26% crude protein was priced at USD0.46 per kg. Pangasius feed prices in the major producing country of Vietnam have increased by 20-25%.

Although fishmeal prices and output have remained stable (Enrico Bachis, IFFO), the inclusion of fishmeal in shrimp feed is limited by Fish-in/Fish-out (FIFO) ratios. So how does the feed segment support the aquaculture industry when the feed ingredient prices do not seem to be easing in 2022?

US consumer prices jumped 6.2% in October, the biggest inflation surge in more than 30 years, according

to Bloomberg. As seafood prices increase in the major consuming markets of the US, EU and China, the margins will cascade down to the producer eventually, but it will not be a smooth process due to supply chain disruptions. The rising food inflation will also make consumers pay higher prices for food and they will adjust to the new normal.

This creates opportunities for novel feed ingredients and protein meals to be more widely accepted. Single cell proteins boast of a high 72% crude protein and are being produced with a small footprint and easy scalability, but investment costs are high. Prior to Covid-19, there was more resistance to the introductory high prices, but this does not seem to be the case anymore when feed companies anticipate a protein shortage. Insect meals are also gaining acceptance but there remains the concern of scalability and production costs. Some companies have been able to secure constant feedstock for the insect larvae from commercial food processing which will improve product consistency. High protein DDG (Dried Distiller's Grains) or Corn Fermented Protein are co-products of the ethanol industry. They can have protein meals ranging from 40-50% crude

protein which because of its existing production capacity, are more ready to supply the markets.

However, the higher prices are not only due to the surge in commodity prices. The Baltic Dry Index, a proxy for freight rates has surged more than 400% since April 2020 during the height of the pandemic. This is due to two factors; one is too much money chasing too few goods and two – both freight and the supply chain are unable to keep up with demand. The industry thinks the earliest shipping issues will normalise in mid-2022 (HJ O'Neil Commodity Consulting).



Feeding the pangasius in Vietnam. In 2021, pangasius feed prices in the major producing country of Vietnam have increased by 20-25%.

## Thumbs up to Ecuador in pivoting shrimp exports

During the pandemic, Ecuador, well recognised as a leader in HOSO shrimp exports, was faced with a hard reality: How to sell its shrimp, said Ecuador's National Chamber of Aquaculture (CNA) Executive President José Antonio Camposano to SeafoodSource.com. Back in 2020, it had already faced problems exporting to China, the main destination for Ecuador's shrimp exports. Even though exports to China resumed in 2021, Ecuador's exporters faced issues with strict checks for the virus on packaging.

How quickly Ecuador pivoted to direct its shrimp into the retail segment in the US and EU market whilst not forgetting China, was cited. Gorjan Nikolik (Rabobank) and Willem van der Pijl (Shrimp Insights) gave their perspectives on this achievement.

"For me the success of Ecuador was how quickly they were able to pivot and to introduce value added shrimp. For a long time, Ecuador was supplying shrimp mainly to China. In 2020-they were depending 80% on China as an export market. China, if you remember, fell off the cliff when they started to make strict checks on the covid-19 virus. Within a couple of months, Ecuadorian products moved to Europe

and to the US, which required much more processed products, but the Ecuadorian producers were able to quickly deliver that. But now China is coming back but Ecuador has already a very strong position in Europe. So overall now, it lowered its dependence on China," said Gorjan Nikolik at an IFFO webinar in October 2021.

"Ecuador's Sustainable Shrimp Partnership (SSP) is another driving force behind the country's desire to diversify its markets. The partnership requires accredited farms to be ASC certified and provide further guarantees of traceability of their products through IBM's blockchain platform: to use zero antibiotics throughout the production process; and to have a neutral impact on the water that they use. With these requirements, SSP aims to set Ecuadorian shrimp apart from others, mainly Asian shrimp. And it's very successful in doing so," said van der Pijl in his blog. The drive for market diversification led to an increase in the volume of certified shrimp that can be supplied to high-end markets especially in Europe and the US. As of October 2021, the volume of ASC certified shrimp is >117,800 tonnes which is 18% of its shrimp production. ([www.shrimpsights.com](http://www.shrimpsights.com))



Ecuador was quick to pivot into the retail segment in the US and EU market whilst not forgetting China.

## Making news in 2021 - Shrimp aquaculture innovators



DELOS, founded by CEO, Guntur Mallarangeng (bottom left), Bobby Indra Gunawan, COO (bottom right) and Alexander Farthing, CSO (top, right) in 2021, seeks to drive the growth and modernisation of the Indonesian aquaculture industry, a vision that they call the "Blue Revolution".

DELOS an Indonesian aquaculture-tech company raised an undisclosed amount of seed funding, led by Arise, a collaborative fund from MDI Ventures and Finch Capital. Its investors also included Irvan Kolonas of JAPFA, one of the largest shrimp feeds and seed producers in the country, and Hendra Kwik of PayFazz, one of Indonesia's most prominent fintech firms.

DELOS is a multidisciplinary team with aquaculture, marine biology, technology and business backgrounds. Partners to the startup include Dewi Laut Aquaculture, a leading local aquaculture company and Alune Aqua, a leading aquaculture fintech firm, to accelerate its rapid development of in-house technologies. The company plans to use the fresh funds to reinforce and scale its shrimp production software which accurately forecasts and recommends actions to improve farm profitability and productivity. Funds will also be used to develop value chain integrations and to grow new farm partners.



As of 2021, JALA's platform is being used by more than 6,700 farms, achieving improvements in productivity and feed conversion ratios, and facilitating the monthly trade of 200 tonnes of shrimp. Figure by Aryo Wirawan, CEO JALA at TARS 2021.

JALA has raised USD6 million from Mirova, Meloy Fund, which is a US-based fund focused on benefiting coastal ecosystems, and Real Tech Fund in November. The company's current investors include Hatch and 500 Global.

The Indonesian start-up uses proprietary hardware and data platforms equipped with functions such as shrimp growth information, harvest prediction, financial

management and disease alerts to transform the shrimp aquaculture business into a more sustainable industry. JALA also operates a marketplace that directly connects shrimp farmers and processing companies, which allows farmers to become more competitive in the supply chain. Another advantage of the marketplace is that it allows for product traceability, an important consideration for consumers.

JALA supports the optimisation of aquaculture pond operations throughout the whole of Southeast Asia. As of 2021, the platform is being used by more than 6,700 farms, achieving improvements in productivity and feed conversion ratios and facilitating the monthly trade of 200 tonnes of shrimp.

Aquaconnect, the Indian aquaculture startup has raised USD4 million in a pre-Series A round co-led by US-based Flourish Ventures and Japan's Rebright Partners. US-based agrifoodtech VC AgFunder also participated in the round alongside Indian family office 6G Capital and existing investors Hatch and Omnivore.

The Chennai-based startup is digitalising the seafood production value chain, connecting smallholder fish and shrimp farmers with suppliers and customers to create "South Asia's largest aqua-farmers' network." It works with more than 30,000 producers across the Indian states of Andhra Pradesh, Gujarat, Odisha and Tamil Nadu.

Farmers can use Aquaconnect's mobile app to access a range of tech-based tools, expert advisory services and financial products which can help them to maximise yields and income. It offers predictive software for pond management which allows farmers to enhance the productivity of their operations and avoid risks such as disease outbreaks. Through its Aquastore marketplace, farmers can buy inputs and have them delivered; while the platform also lets them work with financial service providers and certification bodies and sell their produce to buyers across the globe in a traceable and transparent manner.

XpertSea has been ranked number 23 in Deloitte's Technology Fast 50 program and number 148 in the Deloitte Technology Fast 500. XpertSea is transforming how seafood is farmed and traded. The company was recognised for its rapid revenue growth, entrepreneurial spirit and bold innovation, with revenue growth from 2017 to 2020 calculated at 929%.

In 2021, XpertSea raised USD20 million in a series B funding round led by QEDInvestors and Atlantico with Investissement Quebec joining previous investors Obvious Ventures, Aqua-Spark, Tony Fadell's Future Shape, Real Ventures and edō Capital.

In 2020, XpertSea launched the first data-driven marketplace that uses AI and financial services to connect shrimp farmers with a network of buyers and ensure same-day payment. The marketplace was named Trading Solution of the Year by AgTech Breakthrough, a leading market intelligence organisation that recognises the top companies, technologies and products in the global agricultural technology market. More details: <https://aquaasiapac.com/> and <https://xpertsea.com/>

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# Live SPF polychaetes – a critical need for shrimp broodstock biosecurity and performance

Use of wild caught polychaetes in Asia brings unwanted risks and biosecurity concerns for shrimp hatcheries

By Stephen Christensen and Florian Renault

A quick google search on biosecurity best practices in shrimp aquaculture will yield a lengthy and even daunting checklist for shrimp hatchery technicians. Among all the best practices, one will find “farmer education” listed, but with little information added to this category. This article will focus specifically on live polychaetes as feed for shrimp broodstock, arguably the most important live feed for the entire shrimp rearing cycle, and how we can improve our knowledge, handling and availability of this product for our industry.

Globally, we have become much more knowledgeable on best practices for full biosecurity. We are using the most advanced shrimp aquaculture inputs, from specific pathogen free (SPF) and specific pathogen resistant (SPR) shrimp broodstocks, to high quality manufactured dry diets, probiotics and technically advanced water treatment and filtration systems. However, we are still making risky decisions when it comes to the often overlooked but very important category of live and/or fresh diets required for shrimp maturation and post larvae production. The sourcing and handling practices of these feeds, which range from live *Artemia* nauplii to frozen squid and oysters or live or frozen polychaetes, are in desperate need of improvement.

## Risks associated with live feeds

Live and fresh feeds are vectors for aquaculture related-disease. This is indisputable. Live and fresh feeds also offer performance benefits that manufactured diets have yet to fully match, making it difficult to reduce our reliance on them. To date, if a shrimp hatchery is using polychaetes for shrimp broodstock feed, the industry standard has primarily been to source local, wild caught polychaetes. This entails the local community combing through the ocean shoreline, estuary or riverbeds looking for polychaetes, which are then collected, packed and sent off to customers.

However, it is perplexing that our industry calls for more sustainable aquaculture practices, but continues to purchase this overly exploited natural resource, which happens to be protected by the Biodiversity Act of 2002.

Furthermore, the shortage of wild caught polychaetes, especially during the rainy season in India and Vietnam, often results in unpredictable feeding protocols for shrimp broodstock.

The most dangerous issue with the local, wild caught polychaetes is the high contamination rates of *Enterocytozoon hepatopenaei* (EHP), Early Mortality Syndrome (AHPND/EMS) and Decapod Iridescent Virus (DIV1). The ocean shorelines, estuaries, and riverbeds where local polychaetes are collected are highly contaminated due to water discharged from shrimp hatcheries and farms.

Pathogens are embedded in the sediments where polychaetes burrow, allowing for an easy entry point into the digestive system of the polychaetes. This means that the most expensive input in the shrimp hatchery cycle, imported SPF shrimp broodstocks, are frequently fed contaminated live polychaetes. There is no widespread consensus for disinfecting live polychaetes. All it takes is one contaminated batch of polychaetes and the broodstocks are no longer SPF. This contamination will carry forward to the shrimp nauplii and result in infected post larvae.

## Risks mitigation

What are the solutions available to address the high risk of contamination and unstable supply of live polychaetes? Significant time and research have been committed to small scale experiments in various closed laboratory or R&D facilities. There, polychaetes broodstock have been identified and full rearing cycles have achieved small successes. However, these methods are not scalable to commercial quantities. First, there is the need for significant land and infrastructure investments to farm commercial quantities of polychaetes. Dozens of hectares are required to achieve a production capacity of 200-300kg/day, which puts incredible stress on the farming methods to meet specific production yields to be economical.

There is also the question of biosecurity related to farming polychaetes. Every day, the biosecurity must be perfect to combat the high risk of contamination. We should also heed the recommendations of The World Organisation for Animal Health (OIE), the pre-eminent body for monitoring shrimp aquaculture disease on a country-by-country basis. There is a specific reason why shrimp broodstock maturation facilities are based in Hawaii; this is because OIE recognises that shrimp aquaculture pathogens do not exist there.



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We need to also understand what constitutes the SPF designation. The most comprehensive definition and explanation was published by Alday-Sanz et al. (2018). SPF status for shrimp aquaculture is defined by the following:

*SPF animal stocks must come from a population that has tested negative for specific pathogens for a period of at least two consecutive years, has been raised in highly bio-secure facilities following stringent biosecurity management measures and has been fed with bio-secure feeds. To be able to maintain and claim SPF status, a suitable surveillance program for the specific pathogens, including both molecular and histopathological tools, must be in place.*

The cited article adds further context to the SPF definition by emphasising the geographical area of the farmed animal, in this case polychaetes, which must be “where major shrimp pathogens are known to be absent or at low prevalence.” Accordingly, to qualify for farmed SPF polychaetes designation, the farming must be in a country free of shrimp pathogens recognised by the OIE, with a surveillance program that regularly (e.g. bi-monthly) collects samples of polychaetes from every production basin or pond, and tests for all known OIE listed pathogens from shrimp aquaculture for 24 consecutive months to qualify for specific pathogen free status. These criteria easily point to why shrimp hatcheries only want shrimp broodstock from Hawaii.

In 2021, we conducted a four-month survey in India which covered in-person interviews at more than 29 shrimp hatcheries in Andhra Pradesh in April and May and later in September and October. The survey revealed an overwhelming fear of existing EHP presence in locally sourced polychaetes – farmed or wild caught. The feedback also demonstrated a consensus for frozen, fresh feeds like squid and oysters from wild caught sources off the coast of California. The sourcing of live or fresh feeds for shrimp broodstock simply cannot originate from a shrimp producing country. We must apply this strict

criterion of biosecurity principles to all shrimp maturation live or fresh feeds.

### Specific pathogen free farmed polychaetes

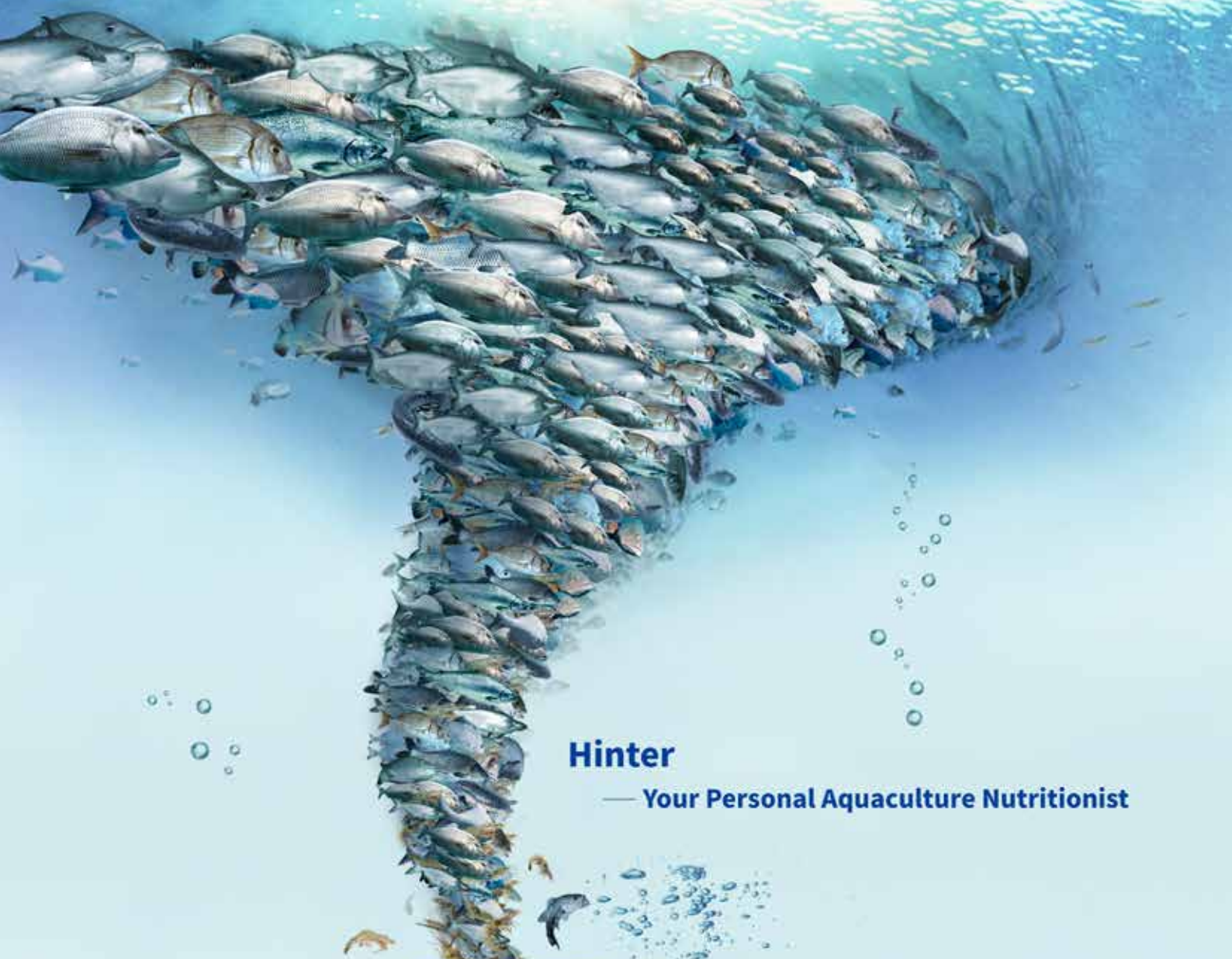
What are the present day solutions that exist and can meet these stringent requirements? Topsy Baits and Delta Farms from The Netherlands are the only known commercial scale SPF polychaete farms in the world and they far exceed the standards for SPF designation. The OIE recognises The Netherlands as free of shrimp aquaculture pathogens (AHPND/EMS, EHP, SHIV/DIV1, IHHNV, IMNV, NHP-B, TSV, WSSV, YHV, CP/A astaci, MrNV, MBV, BP) which means that there is zero risk of contamination due to in-country shrimp production.



Farmed specific pathogen free (SPF) polychaetes in Europe. *Nereis virens*, a cold-water polychaete species farmed by Topsy Baits and Delta Farms, can only be farmed in specific, cold temperature climates (5 to 10°C).

	SPF polychaetes (Topsy Baits)	Wild caught polychaetes (Vietnam)	Wild caught polychaetes (India)
Protein (%)	13.49	8.33	3.09
Protein (dry matter) (%)	72.5	53.2	44.5
Hydrolysed fat (%)	2.06	0.79	0.77
Moisture (%)	81.4	84.35	93.06
Fatty acids (mg/100g)			
Eicosapentaenoic acid (EPA)	135.1	21.4	15.4
Docosahexaenoic acid (DHA)	23.0	4.1	3.0
Arachidonic acid (ARA)	47.4	23.8	17.2
Sum of omega-3s	363.5	41.1	29.6
Sum of omega-6s	196.3	74.5	53.7
Saturated fatty acids (SAT)	369.5	184.0	80
Monounsaturated fatty acids (MUFAs)	379.0	105.3	150
Polyunsaturated fatty acids (PUFAs)	798.6	126.6	70
Total fatty acids	1547.1	415.9	300

**Table 1.** Comparison of proximate and fatty acid composition of polychaetes; SPF polychaetes from Europe against wild caught polychaetes from Vietnam and India.



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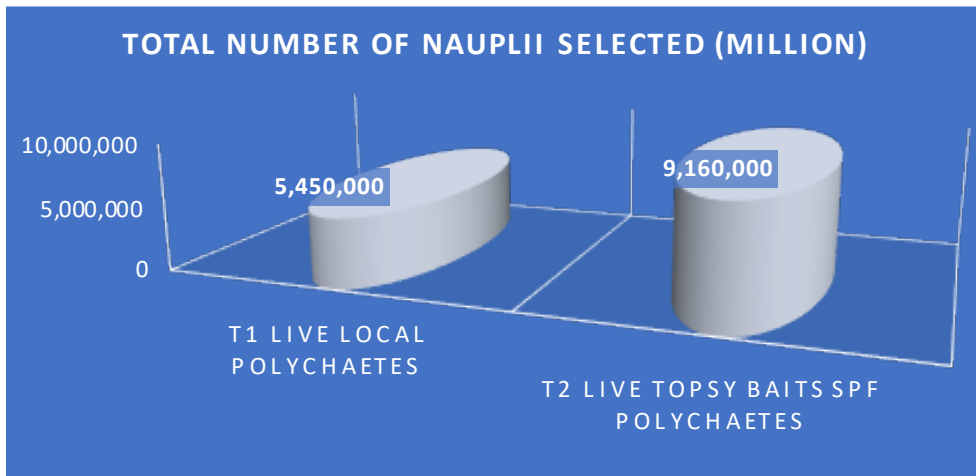
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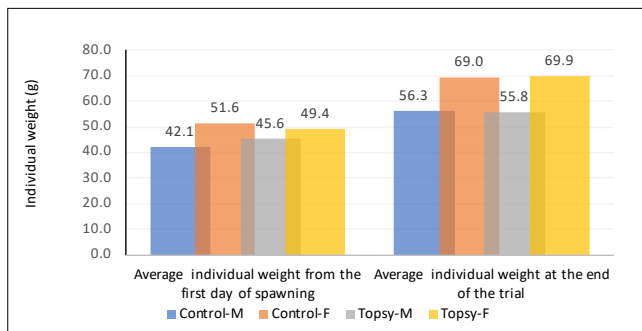
Add: No.56, the 2<sup>nd</sup> Xingui Road, Guangzhou High-tech Industrial Development Zone, Guangdong Province, P.R. China



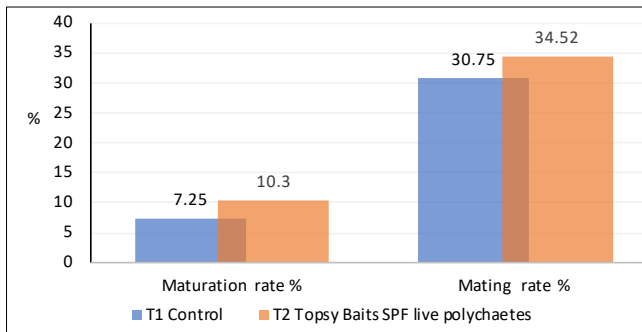
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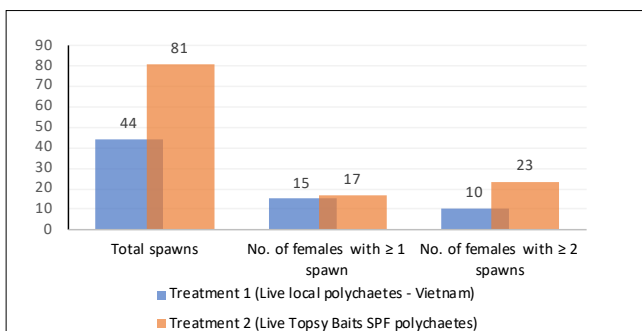
**Figure 1.** Total numbers of nauplii selected produced; T1, broodstock fed live local polychaetes (Vietnam) and T2 broodstock fed live Topsy Baits SPF polychaetes. There were 37 pairs of broodstock and the duration of the trial was 7 weeks.



**Figure 2.** Average individual weight of broodstock on day 1 to end of the trial (M=males; F=Females, Topsy = SPF polychaetes from Topsy Baits, Netherlands).



**Figure 3.** Comparison on maturation and mating rate (%) between broodstock fed live local polychaetes (Vietnam) and spawners fed live SPF Topsy Baits (TB) polychaetes.



**Figure 4.** Spawning of broodstock fed live local polychaetes (Vietnam) and broodstock fed live Topsy Baits SPF polychaetes. The number of weeks from the first spawning until the end of the trial (Treatment 1 = 6 weeks and Treatment 2 = 7 weeks).

For more than 30 years, Topsy Baits has performed routine sampling and testing of the polychaetes with local authorities and since 2012, they have utilised the University of Arizona’s Aquaculture Pathology Laboratory for regular testing. Their SPF status is confirmed by two independent sources, with zero pathogens detected, to date. This is the standard we must adopt for any live or fresh maturation diets.

Farming polychaetes outside of tropical climates native to shrimp farming countries also has performance related benefits. *Nereis virens*, a cold-water polychaete species farmed by Topsy Baits and Delta Farms, can only be farmed in specific, cold-temperature climates (5 to 10°C). It has a significantly higher nutritional profile compared to local polychaetes found in tropical countries, such as India and Vietnam. Table 1, which highlights the nutritional profile of *N. virens*, shows its clear superiority across all parameters when compared to wild caught polychaetes found in India and Vietnam. This nutritional superiority of *N. virens*, when compared to tropical origin polychaetes, will result in an increase of the nauplii number per female (Figure 1 and 2); increase in mating and in maturation rates (Figure 3); offers better recovery after each spawning (Figure 4), increase the quality of the sperms, increase the quality of the eggs (higher hatching rate) and offer full traceability from the worms to the final shrimp post larvae.



**Stephen Christensen** and **Florian Renault** are Co-Founders of SPF Shrimp Feeds, an aquaculture feed supplier focusing exclusively on live, fresh and natural diets for both shrimp maturation and larval stages with specific pathogen free (SPF) status, tested and certified by the University of Arizona’s Aquaculture Pathology Laboratory, USA. Email: [info@SPFshrimpfeeds.com](mailto:info@SPFshrimpfeeds.com) [www.spfshrimpfeeds.com](http://www.spfshrimpfeeds.com)

# 30 years of tilapia breeding programs: The effect of traditional and novel selection methods

The simplistic selection based on observed physical traits has evolved into the use of DNA-information to supply the farmers with premium differentiated Nile tilapia fingerlings.

By Rajesh Joshi, Anders Skaarud and Anne Vik Mariussen



Tilapia aquaculture has grown tremendously in the past 30 years from barely 400,000 tonnes in the early 1990s to around 7 million tonnes in 2021. Nile tilapia is today the most widely farmed fish species in finfish aquaculture, playing an important role in food security and generating income and employment in many parts of rural Asia, Latin America and Africa.

## One of the most important input factors

Behind this impressive development, there is increasing adoption of tilapia farming due to the expansion of farming areas and new farming methods used. Of all farm input technologies, breeding and genetics are among the most important contributors to improvements in productivity. Several of today's tilapia breeds far exceed the performance of their original wild ancestors. Breeding technology has resulted in accumulative gains that contribute to a healthy and profitable industry.

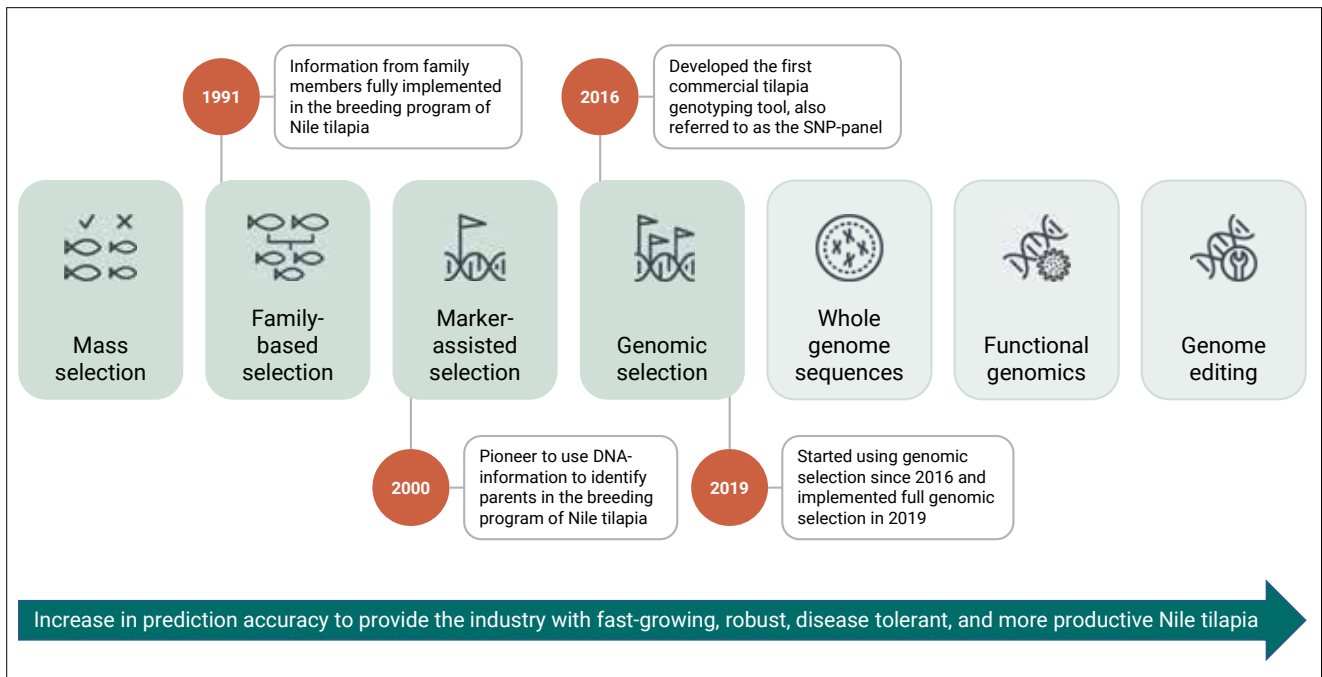
We, GenoMar Genetics Group, have been at the forefront of this development by consistently investing, innovating and managing tilapia breeding programs and

disseminating genetic progress to farmers. Under the brands GenoMar, Aquabel and AquaAmerica, we currently distribute more than 500 million fish to customers in Asia and Latin America annually and this number is growing rapidly every year.

## Pioneers in novel breeding technology

In 2021, we are celebrating the 30th anniversary of our work with Nile tilapia breeding and we have prepared a couple of articles to describe this important achievement. In the first article published in issue November/December 2021 we focused on the breeding programs and the evolution and future direction of our selection goals.

This is our second article where we have summarised the innovations and incorporation of breeding technologies in commercial Nile tilapia breeding programs (Figure 1). GenoMar Genetics has always been the pioneer in the implementation of these innovative breeding technologies in Nile tilapia to contribute to a healthy, profitable and sustainable industry.



**Figure 1.** Different available breeding technologies used in breeding programs, with the arrow indicating advancement of the methods. The technologies with the lighter green colour to the right have not yet been implemented in regular Nile tilapia breeding programs, but research is ongoing. The figure also shows the actual dates of the inclusion of various technologies in the routine genetic evaluation of the GenoMar breeding nucleus.

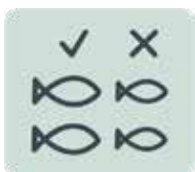
## From simple to advanced selection methods to increase genetic gain

Breeding technologies can be defined as the science and technologies used to select the best performing individuals for a more profitable and sustainable tilapia industry. These technologies are used to rank the breeding stock population from best to worst and based on this ranking the best individuals are chosen to serve as the parents of the next generation. The accuracy of this ranking helps breeding companies to achieve higher genetic gain and to provide better-customised products to the market.

Over the last three decades, science has experienced various developments in breeding technologies to increase the accuracy of these rankings, from a simplistic method of selection based on observed physical traits to the complex method of incorporating DNA-information into breeding decisions, which is described in detail below.

### Traditional selection methods

#### Mass selection using observed physical traits



One of the earliest selection methods, mass selection is still prevalent in small-scale and in-house tilapia breeding programs, where the fish are ranked based on the observed physical traits (phenotypes). It is often called selection on own performance and is an easy, simple

and cheap way to select the broodstock without the need for any advanced technical knowledge.

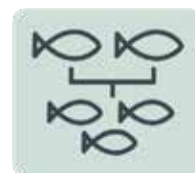
The success of mass selection depends on the contribution of genetics to the phenotype. It has been

widely shown that phenotype is a function of genes, environment and the interaction between these two. For traits such as growth, the contribution of the genes to the phenotypic variance (called heritability) is on average around 30 percent, implying that the mass-selected broodstocks do not represent the best method for ranking the genetically best broodstock in the population. Further, for those traits which cannot be measured in the living fish (e.g., fillet yield), fish cannot be selected.

Another disadvantage of this method is that it is usually not possible to know which family a fish is from. A family with good genes will produce a lot of good fish, many of which will be selected for the next generation which increases the inbreeding level and decreases the genetic diversity in the breeding population. This makes it difficult for the breeding program based on mass selection to be continued for many generations.

#### Family-based selection using information from family members

A more advanced, method of selection uses information from family members of the fish (family-based selection) in statistical models to dissect the genetic merit of breeding candidates and rank them. Best Linear Unbiased Prediction (BLUP) has been the gold standard statistical model for determining the genetic merit of an individual until recently. The method was developed and perfected during the 1940s to 1970s in parallel with improvements in computing power.



BLUP provides for very accurate estimates of genetic values, thereby giving accurate ranking of the fish because it accounts for non-genetic differences between individuals such as a pond, temperature or hatching day

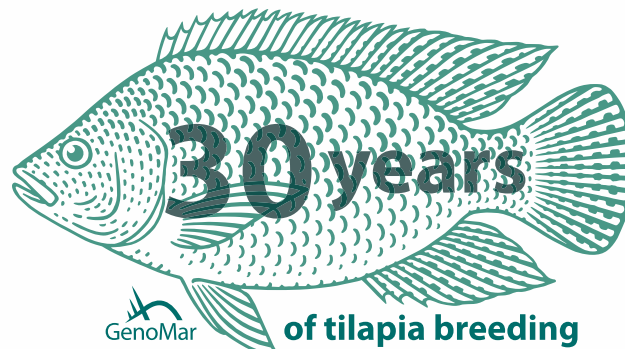
# Better growth and survival start with the right genes

GenoMar Genetics is committed to professional and innovative tilapia breeding of the continued populations collected from Africa and Asia in 1988.

We have just finalised the 30<sup>th</sup> generation of selective breeding to support a healthy and profitable tilapia farming industry worldwide.

Our genetically improved fingerlings and juveniles are delivered all year round and have documented superior traits for:

- Growth rate
- Fillet yield
- Robustness
- Specific disease resistance



as well as incorporating performance information from all relatives (parents, grandparents, offspring) in the pedigree.

GenoMar was a pioneer in the application of BLUP methodologies in the breeding program of tilapia. In family-based selection the pedigree of the selected fish is known, so measures can be taken to limit the inbreeding rate. This allows for the genetic diversity to be maintained and the breeding program to stay sustainable for many generations.

### **Marker-assisted selection using DNA-information**

One important prerequisite for using family-based selection is to give an accurate ranking of the broodstock without errors in the family relationships. Thus, to produce accuracy, GenoMar started to use the DNA-information (microsatellite markers) to identify the parents and other family members in the tilapia breeding program from 2000. GenoMar has therefore been using the available advanced technologies in the breeding program since the very beginning.



### **Genomic selection using comprehensive DNA-information: From family ranking to individual ranking**



During the 2000s a paradigm shift took place in animal breeding with the arrival of genomic selection or genomic prediction methods. The concept was first introduced in 2001 by Professor Theo Meuwissen et al. and has been gradually implemented in the livestock industry during the past decades.

The basic principle of genomic selection is that the genetic variation found in the genomes (which is typically just the difference of around 1-3 percent in the genome of different individuals) is a primary contributor to the

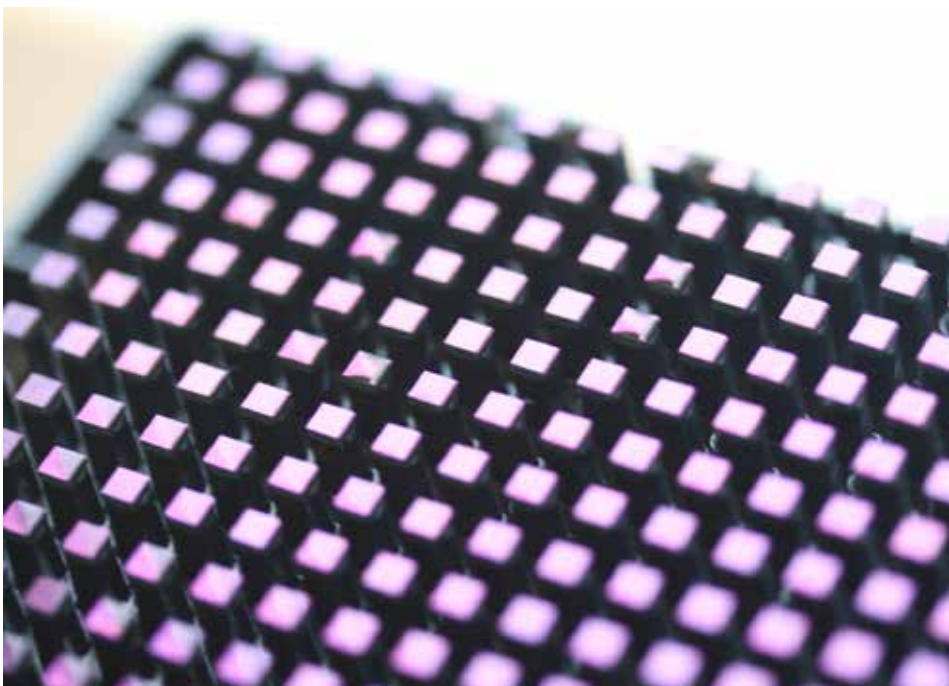
differences we see in the phenotypes (observed physical traits). Complex mathematical models can determine the contribution of each of these variants to the phenotype and thus enable the determination of a "genomic breeding value" of an individual once its genotype is known.

### **Genomic resources and the first genotyping tool for tilapia**

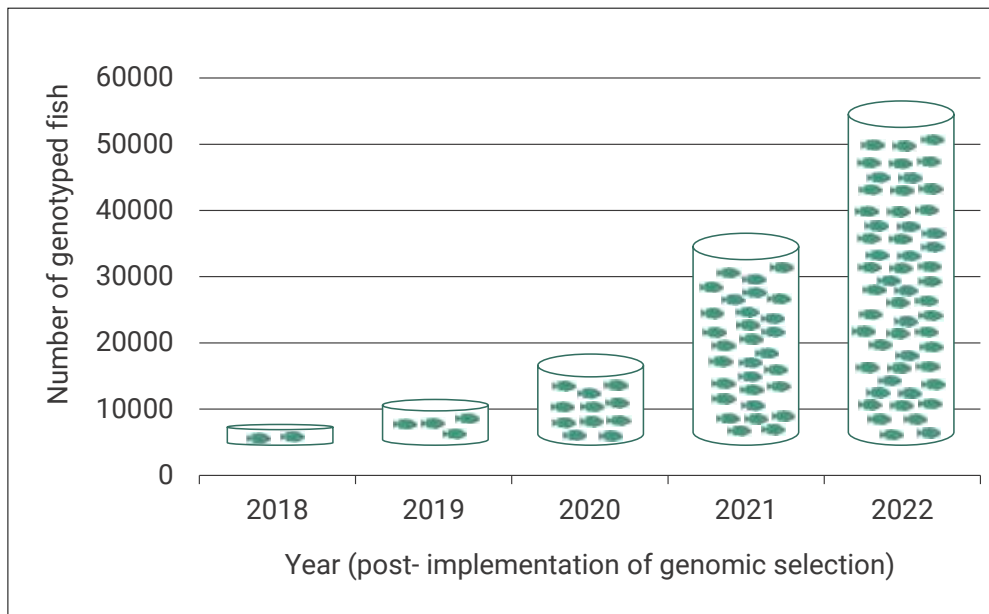
GenoMar developed the first commercial tilapia genotyping tool, also referred to as the SNP (single nucleotide polymorphism) - panel in 2016. We revealed more than 2 million places in the tilapia genome where fish differ from each other at a single nucleotide and selected ~ 60,000 of those SNPs to construct the first SNP-panel to be used commercially in tilapia breeding (Figure 2).

We were also involved in developing the highest-density linkage map for Nile tilapia, which is helpful to find the order and positions of different SNPs (with reference to the different chromosomes) present in the SNP-panel. This linkage map was used to correct the reference genome assembly and we were involved in the production of the current reference genome assembly. The size of this tilapia genome is around 1006 Mbp, meaning that  $1006 \times 10^6$  base pairs of Nile tilapia DNA has been deciphered and correctly positioned in order. These resources have not only helped us but the entire scientific community and industry to find the position of the genes responsible for various traits.

Today 100 percent of the candidate fish in our breeding programs are genotyped and selected based on genomic breeding values. Thereby, the number of genotyped fish is increasing every year (Figure 3). In 2022 we expect to genotype around 50,000 fish providing us around 3 billion sequences of information contained in the DNA of our breeding population. This huge investment in genotyping followed by other huge investments in computing powers and resources will help us to supply premium differentiated Nile tilapia fingerlings to the farmers.

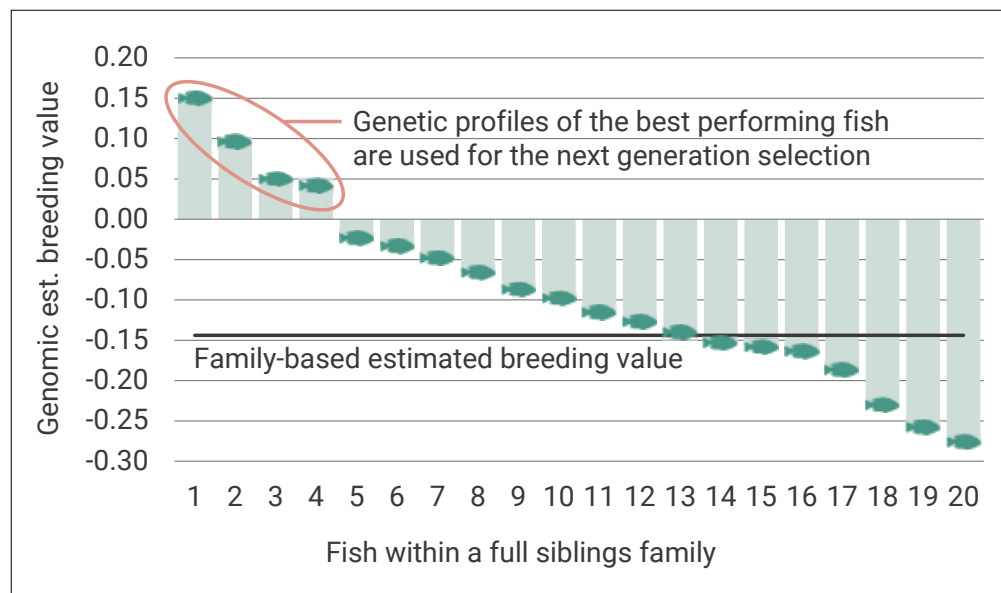


**Figure 2.** SNP-panel (genotyping tool) used for genotyping Nile tilapia for genomic selection. GenoMar developed the first commercial tilapia SNP-panel in 2016.



**Figure 3.** The number of genotyped fish per year post-implementation of genomic selection in the breeding programs. The numbers for 2022 are our forecast based on the planned phenotyping for all traits in different breeding programs.

**Figure 4.** Prediction of the breeding values of 20 individual fish in a full siblings family (breeding candidates) based on the information/phenotype obtained from a pathogen challenge test. Family-based selection provides only one breeding value for the whole family (as shown by the horizontal line). Whereas the genomic selection provides different breeding values (Genomic estimated breeding values) to every fish based on their genetic merit (as shown by vertical bar charts) enabling us to select the best candidates for precision breeding.



## What are the advantages of DNA information?

DNA-information (genotypes) is used to improve the quality of the breeding decisions in tilapia family breeding programs by:

### 1) Precision-breeding: More accurate prediction of breeding values for traits that are not possible to measure on candidate fish

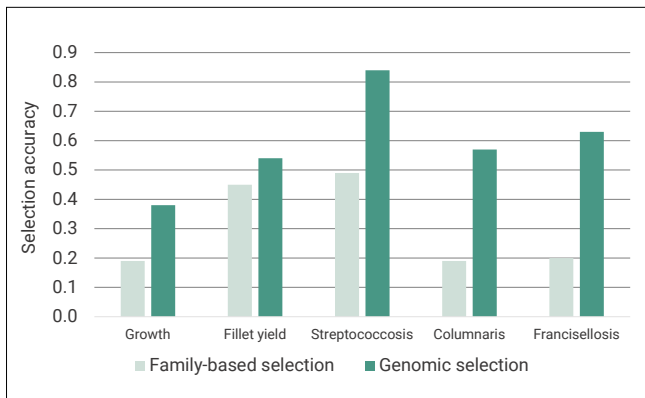
Measuring traits such as fillet yield or resistance to specific diseases cannot be done on selection candidates because it requires either the sacrifice of the fish or exposure to standardised pathogen challenge tests. This makes it impossible to use those fish as candidates for the next generation. Until recently, selection for such traits depended on the measurement of the traits in a group of siblings and the determination of the best families. By this, we could only rank the families from

best to worst and were unable to rank the fish within the families for such traits. Genomic selection provides, however, the opportunity to even select the best fish within the families, thereby increasing the accuracy to list the fish from best to worst for selection decisions, as shown in Figure 4.

This has been possible by providing the actual relationship between individuals. A more accurate relationship between individuals provides a precise ranking of the breeding candidates. Using family information, the relationship between half-siblings (sharing one common parent) is 0.25, full siblings (sharing both parents) is 0.5 and unrelated individuals (no common parents) is 0. Genomics, on the other hand, helps us to determine the actual proportion of the shared genome between the individuals (e.g., some full siblings might be more related than others).

**2) Understanding the genetic architecture of traits**

Different traits have varying characteristics. Some of the traits are controlled by only one gene, whereas some of the complex traits are controlled by multiple genes located in various parts of several chromosomes. DNA-information together with the available genomic resources helps to understand the architecture of the traits and find the causative gene and mutations responsible for the variation in a trait, which can be utilised in breeding decisions. For example, the gene Amhy (Y-specific duplicate of the anti-Müllerian hormone) has been identified to be responsible for the male sex determination and the SNP/mutation of the gene in the population. This gene helps us to identify the sex of the tilapia fish, as early as possible, before sexual maturity.



**Figure 5.** A comparison of accuracy between two selection methods for some traits. The level of detail in the data and the relationship between the family members give different precision in the selection of breeding candidates and the gain achieved in the offspring.

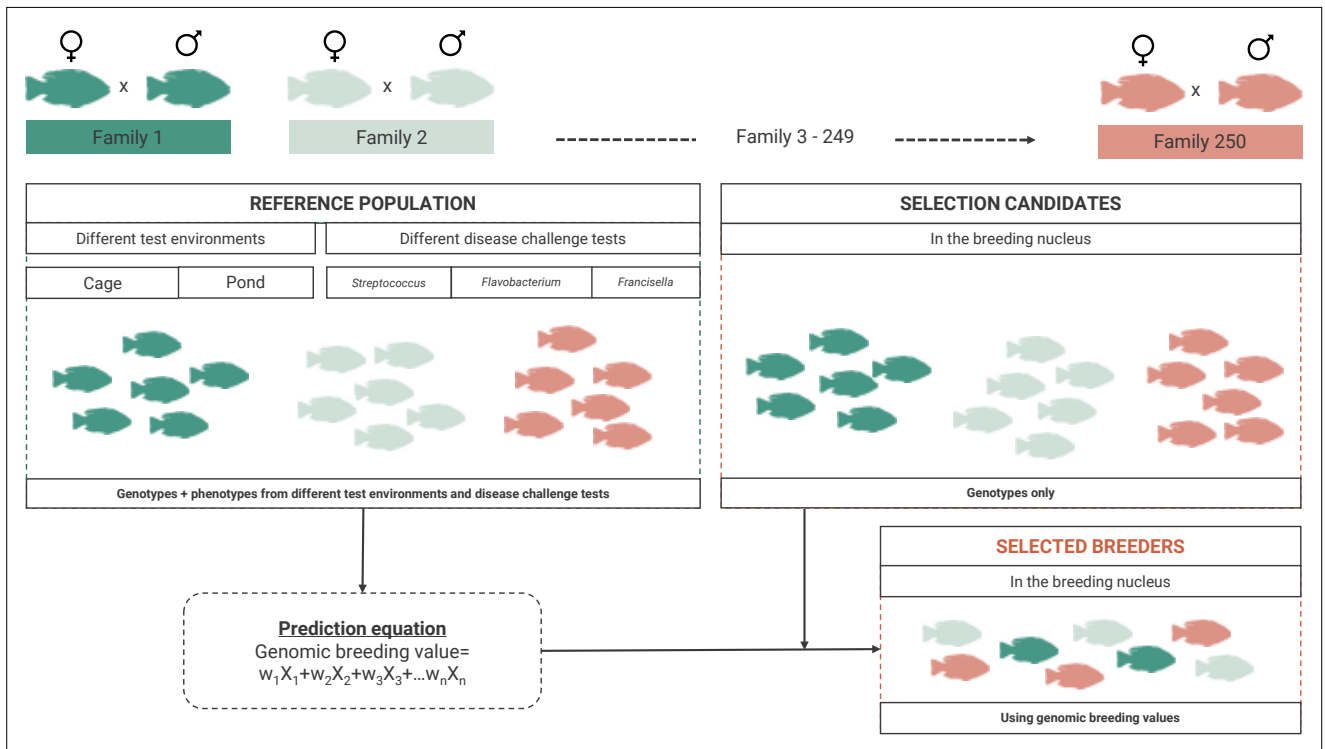
**Proof of concept to show that genomic selection beats the traditional selection**

Scientists use the breeder’s prediction equation formula to calculate the genetic gain that can be achieved in a generation by selective breeding in a population, which is directly proportional to the statistical capacity to produce the accurate ranking of the breeding candidates, also known as the accuracy of selection. Assuming that other factors remaining constant, the increase in the prediction accuracy directly translates to the increase in the genetic gain. Thus, proof of concept on the application of genomic selection to the increase in the prediction accuracy for various commercial traits was performed from 2016 onwards in the GenoMar and Aquabel strain. It showed that the prediction accuracy could be substantially improved using genomic selection in the breeding program (Figure 5), not only for growth traits, but also for all the traits included in the breeding program. For example, the rate of genetic gain of 55g/generation for body weight at harvest using family-based selection methods could be increased to 111g/generation using genomic models.

**Implementation of genomic selection to create more value in tilapia production**

The promise of substantial genetic gain for various traits using genomic selection (Figure 5) prompted GenoMar Genetics to implement full genomic selection in the GenoMar strain since early 2019, the Aquabel strain from 2020 and the AquaAmerica strain from 2021.

After spawning, offspring from each family is divided into reference population and selection candidates (Figure 6). The selection candidates are grown in the secure breeding



**Figure 6.** Schematic overview of the breeding work in the GenoMar tilapia populations to select the best breeding candidates. Offspring from every family is tested under different conditions and data (phenotypes and genotypes from each fish) are collected and used to pick the preferred candidates for the next generation.

nucleus facility, whereas fish from the reference population are sent to different test environments (e.g., cages, different ponds, etc.) and for separate disease challenge tests (e.g., *Streptococcus*, *Flavobacterium*, *Francisella*, etc.). This enables the collection of various phenotypes on the fish from the reference population. All the fish in both the reference population and the breeding nucleus population are then genotyped. Thus, selection candidates only have genotypes, whereas the reference population has both phenotypes (from different test environments and challenge tests) and genotypes.

The prediction equations are after that solved using phenotypes and genotypes of the reference population to obtain the SNP-effects of all the markers in the SNP-panel. These SNP-effects are then used in the genotyped fish from the breeding candidates to calculate the genomic breeding values of the selection candidates. Now fish in the breeding populations are ranked from best to worst for all the traits and the required number of breeders for the next generation are selected.

### Perspectives and future developments

Selective breeding of plants and animals have experienced impressive developments over the past 10,000 years since mankind started to cultivate them for various purposes. Innovation and technology disruption in the field have transformed crop and animal breeding from an intuition-based farmer's decisions to a complex data and technology-enabled discipline carried out by specialised breeding companies. These companies have the focus, resources and scale to make investments in R&D, infrastructure and talent required for serious and professional breeding work. Proof of that is the continuous evolution in methods applied to the breeding of tilapia in the past 30 years as well as the ongoing consolidation of the breeding sector into a few specialised global companies which mirror similar developments in other crop and animal species.

Scientists and breeding companies continue to develop new knowledge and new methods to develop the next generation of farmed animals and plants that will be part of the solution to some of the most pressing issues facing humanity: food security for 10 billion people in 2050, biodiversity decline and impact of climate change on ecosystems and farm environments. The need for efficiency, resilience and welfare in our food production systems has never been greater with the huge demand for

the science of breeding and genetics to offer solutions. We present some of those possible future developments in Nile tilapia selective breeding below:

High-throughput phenotyping techniques and sensor technology will enable the collection of novel phenotypes and traits that has never been measured before as well as improvements in the way we measure traits today. Examples of novel phenotypes and traits are molecular phenotypes (RNA, proteomics) behavioural, sustainability or feed efficiency traits. Non-invasive trait collection for carcass evaluation will allow improvements in the percentage of edible meat in tilapia which today is relatively low compared with other farmed animals.

More knowledge about the tilapia genome and genetic architecture of traits will reduce the need for identifying the best animals from an existing pool of candidates, but instead introducing favourable genetic variants and traits into the farming genotypes by using new gene editing techniques such as CRISPR-CAS9.

We thank our shareholders, customers, employees and stakeholders for enabling 30 years of breeding work and we look forward to celebrating the next anniversaries together with you.



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All are from GenoMar Genetics Group, Norway.

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## The thrill of krill

The benefits to fish and shrimp come from a combination of amino and fatty acids mixed with chitin, astaxanthin, dietary phospholipids, vitamins and other low molecular weight soluble attractants in the diet

By Lena Burri

Seafood contains important nutrients, such as the long chain omega-3 polyunsaturated fatty acids (n-3 PUFAs), eicosapentaenoic acid (EPA) and docosahexaenoic (DHA), which terrestrial animal and plant products typically lack. On top of that, seafood is a rich source of additional nutrients, such as amino acids, vitamins and minerals.

The diet given to farmed aquaculture species must contain all essential nutrients to produce healthy and high quality animal products for human consumption. Krill meal, in addition to being a rich source of protein and lipids, also provides other essential nutrients, such as antioxidants, vitamins and minerals that make it one of the superfoods in the aquafeed sector, known for its high palatability and attractability (Tou et al., 2007).

### Antarctic krill

The Antarctic krill (*Euphausia superba*) is found in the Southern Antarctic Ocean. The up to 6cm large krill aggregate in large swarms, where they feed on microscopic algae. Following the saying 'you are what you eat', krill accumulate many of its special biochemical properties from the tiny 'vegetarian' snack. The carotenoid pigment required to synthesise astaxanthin, for example, is first constructed by phytoplankton. Fuelled by sunlight, the photosynthetic plankton also produces significant

quantities of triacylglycerol and phospholipids quickly gobbled up by hungry krill (Hamner et al., 1983; Hellesey et al., 2018). Krill are such effective algal planktivores that each consumes up to 20% of their body weight per day. Lacking light in the deep ocean, krill evolved to emit yellow-green light periodically from specific bioluminescent organs distributed across its body.

### Sustainable krill biomass

Krill meal is produced from krill caught exclusively in area 48, off the Antarctic peninsula, where the catch is limited to 1% of the total estimated biomass.

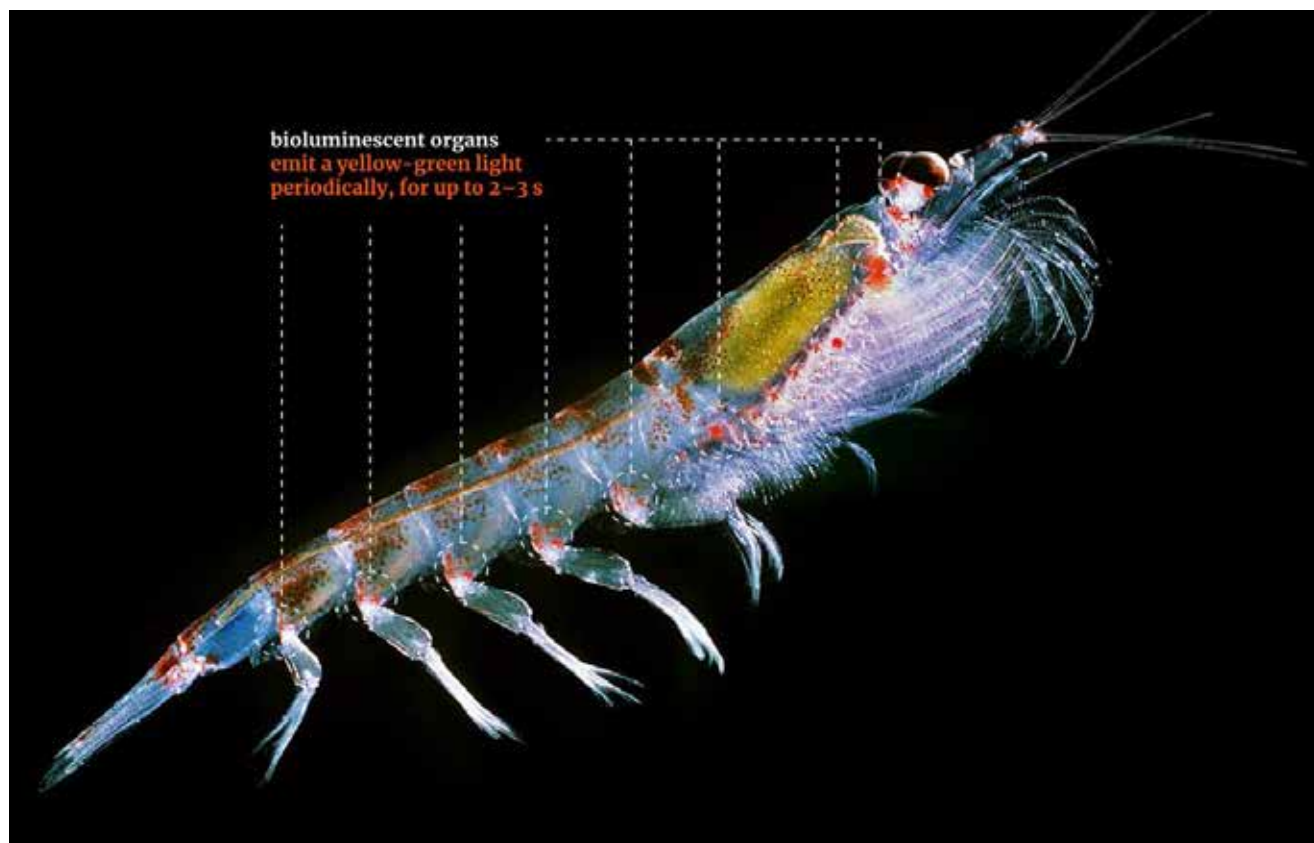
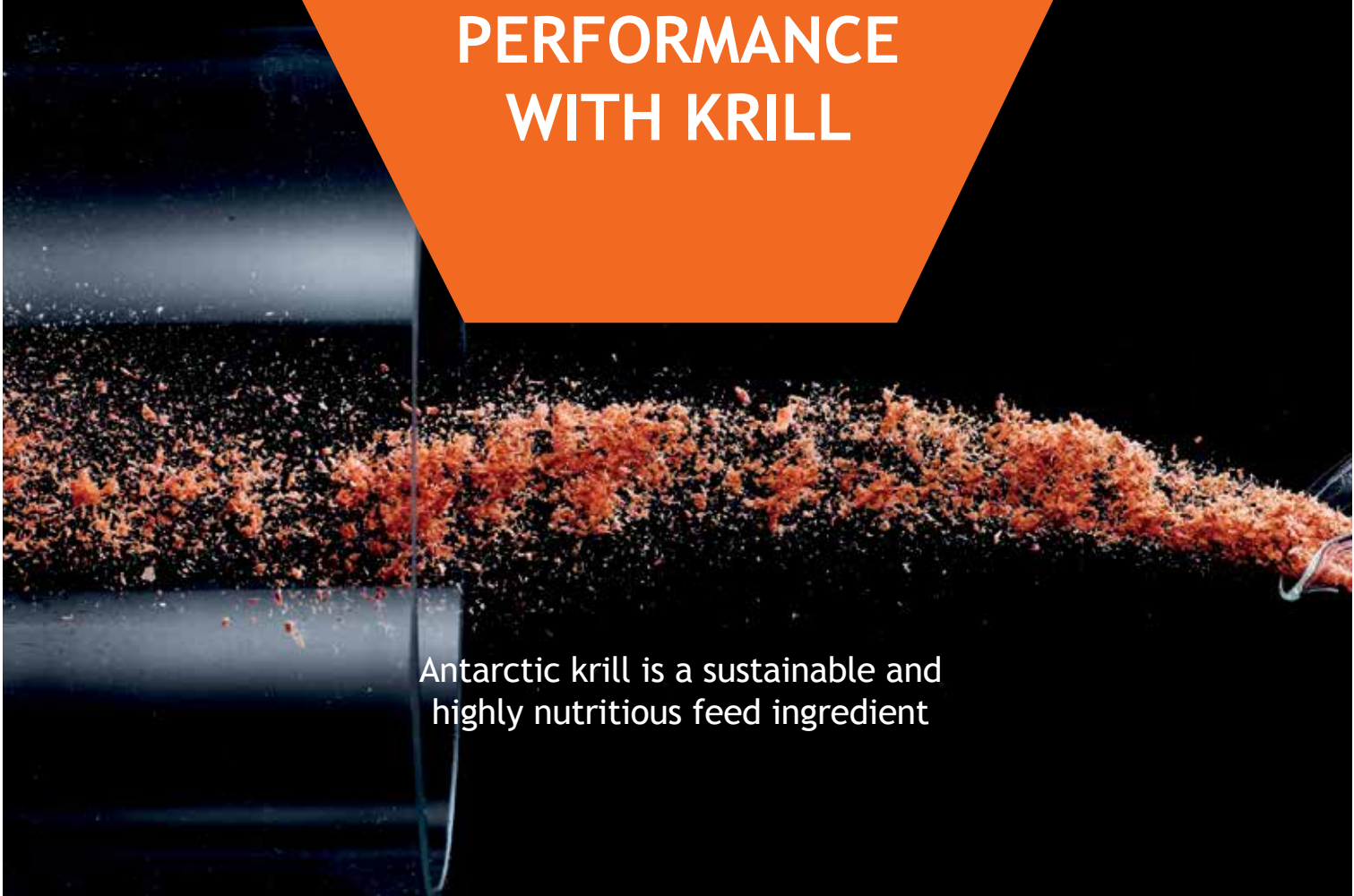


Figure 1. Illuminating the function of bioluminescent organs in krill. Photo by Uwe Kils, licensed under CC BY-SA 3.0.



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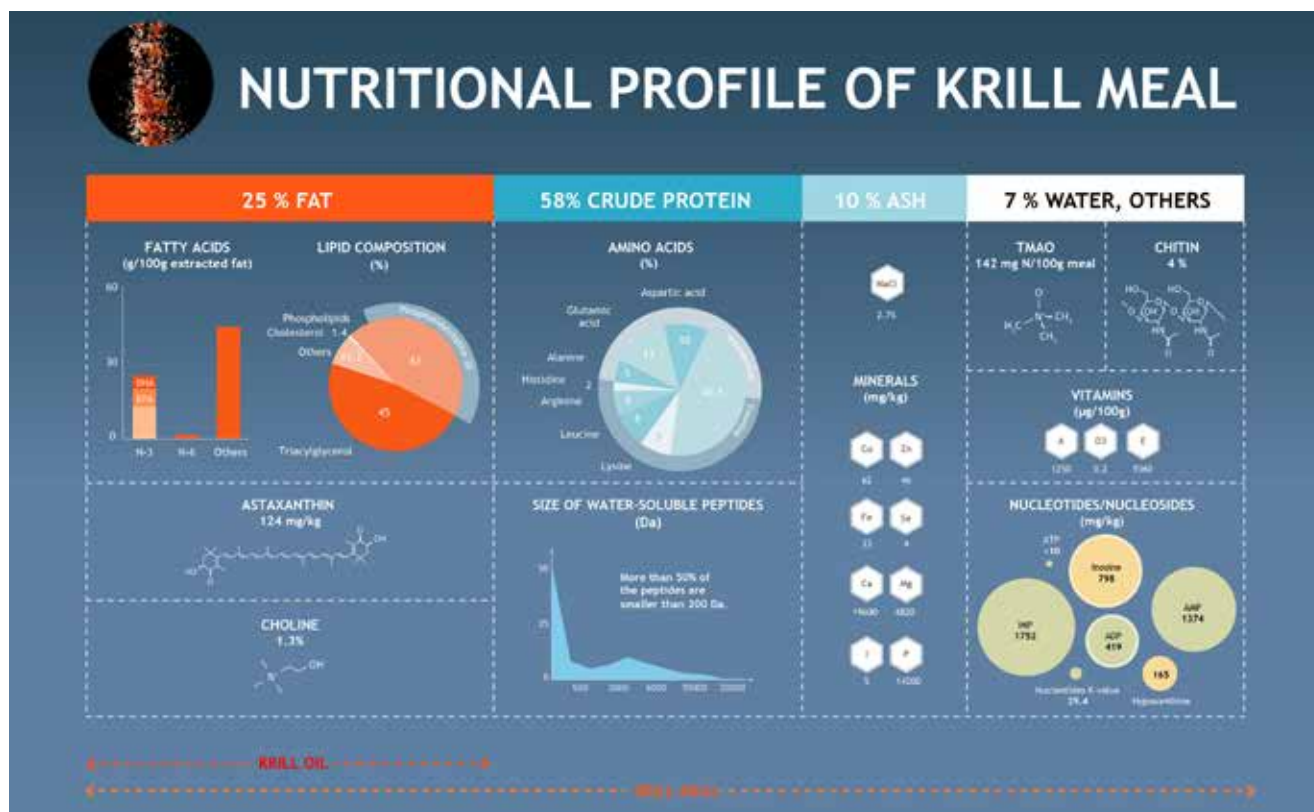
Enhanced growth



Reduced costs

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**Figure 2.** A complete nutritional profile of krill meal including typical values of macronutrients, essential fatty and amino acids, as well as important feed attractants and biochemical components. ADP: Adenosine diphosphate; AMP: Adenosine monophosphate; ATP: Adenosine triphosphate; DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid; IMP: inosine monophosphate; TMAO: Trimethylamine N-oxide; K-value represents the ratio of Inosine to Hypoxanthine with smaller values implying increased freshness (Scale example – Sashimi-grade sushi: ~20; commercially available fish: ~30–45).

The estimated biomass has increased from 60.3 million tonnes measured in 2000 to 62.6 million tonnes in 2018/19 according to findings from the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR). The conservative catch quota and trends in biomass explain why krill stocks count amongst the best managed and underutilised marine resources to date. Aker BioMarine's krill harvesting is also notable for near-zero by-catches, fully transparent operations and the Marine Stewardship Council (MSC) certification. In 2020, the krill fishery received an "A" rating by the Sustainable Fishery Partnership with a biomass that is rated "in very good condition."

### Krill meal is the superfood amongst animal feeds

The realisation that many fish stocks are overexploited has caused a shift away from including fishmeal in animal feeds. However, the rich nutritional profile of krill meal makes this product an ideal supplement to fill the nutritional gaps of more sustainable plant-based or alternative animal diets (Suresh et al., 2011; Sabry-Neto et al., 2017).

#### Proteins

Krill meal contains up to 60% of protein with a well-balanced amino acid profile (Nunes et al., 2011) and small, easily digestible peptide sizes. Certain essential amino acids are, however, much more common in krill meal than in fishmeal, which has consequences for growth performance. For example, the amino acids arginine, glutamic acid, histidine and leucine, which are represented in much higher quantities in krill meal than in fishmeal, were directly correlated with specific growth rate and weight gain in grower walleye pollock (*Gadus chalcogrammus*, Choi et al., 2020).

When krill meal compensated the reduction of fishmeal content in the diets of Atlantic salmon (*Salmo salar*), salmon grew equally well, if not faster initially when the diet contained more krill meal (Olsen et al., 2006). Similar results were found for cultured rainbow trout (*Oncorhynchus mykiss*, Wei et al., 2019). The superior amino acid profile in combination with the low molecular weight soluble nucleotides and small peptide sizes might be the underlying reason for this improved performance.

The study by Sabry-Neto et al. (2017) exchanged a fishmeal-based white leg shrimp (*Litopenaeus vannamei*) diet with a plant-based diet, but added krill meal at four levels (0.5, 1, 2, and 3%). Most of the protein in the diets originated from soybean meal, a more sustainable source of protein than fishmeal and the addition of krill meal supplemented essential nutrients and improved feed attractability. Even at a krill meal inclusion as low as 1%, feed conversion rate improved and at 2 and 3% krill meal inclusion, growth performance improved by 16.3 and 20.1%, respectively (Sabry-Neto et al., 2017). A comparable effect was observed in Tilapia (*Oreochromis niloticus*), where exchanging a diet with 20% fishmeal with one based on soybean meal, but with 3% krill meal, increased growth by 28% (Gaber, 2007). This underscores the nutritional benefit arising from krill meal protein for several commercially valuable aquaculture species.

#### Lipids

Lipids are another group of vital macromolecules. Akin to proteins, lipids play essential roles in metabolic processes such as the storage of energy, signalling information between cells and forming hydrophobic structural components of cell membranes. Lipids come in many forms from fatty acids, triacylglycerol

to phospholipids. But certain essential n-3 PUFAs (polyunsaturated fatty acids), like docosahexaenoic acid (DHA) or eicosapentaenoic acid (EPA), cannot be biosynthesised *de novo* by many organisms or at least not in sufficient quantities. They must have a dietary source to guarantee performance. Nutritional supplementation with rich sources of these fatty acids is therefore vital.

Krill meal contains around 25% lipids where DHA and EPA make up more than 20% of its fatty acids (Burri et al., 2016). But in contrast to fish oil, where n-3 PUFAs are bound to triacylglycerol, these fatty acids in krill meal are packaged with phospholipids. This, in turn, allows n-3 fatty acids from krill meal to be incorporated into cell membranes more effectively (Rossmeisl et al., 2012). Amplified phospholipid levels supplied from krill, for instance, increased growth and survival in fry of Atlantic salmon (Taylor et al., 2015), the larvae of the large yellow croaker (*Larimichthys crocea*, Feng et al., 2017) and seabream (*Sparus aurata*, Saleh et al., 2013). In the offspring of Atlantic halibut (*Hippoglossus hippoglossus*), the broodstock diet on krill meal improved offspring fatty acid profiles (Mazorra et al., 2003). Besides, the primary phospholipid found in krill meal - phosphatidylcholine - also supplies choline.

Choline is a vital vitamin-like nutrient involved in neurotransmission and osmoregulation. Particularly in aquaculture organisms with both freshwater and marine life stages, like the salmon, where osmoregulation is challenged, choline may support a low-stress transition between these environments.

### Feed attractants

Phospholipids are also feed attractants, although krill meal additionally contains other feed attractants like chitin, astaxanthin and low molecular weight soluble nucleotides, amino acids and trimethylamine N-oxide (TMAO) (Xie et al., 2019; Wu & Bechtel, 2012; Ali et al., 2007). Such feeding effectors elevate feed attractability and palatability while they reduce feeding latency time, which in turn reduces nutrient leaching and feed wastage. For aquaculture production, this means lower nutrient pollution, fewer costs and less time spent cleaning. For the farmed seafood, feed attractability translates into increased feed intake and, therefore, growth. Furthermore, these feeding effectors enrich krill meal to allow farmed animals to cope with stressful situations such as high density, transfer stress, salinity or temperature changes and diseases.

Feed attractability is, therefore, an important consideration when formulating feeds. In a study that compared the effects of 3% krill meal inclusion on the attractability of a plant-based feed for white shrimp with six marine feed stimulants, feeds containing krill or shrimp head meal were preferred owing to their superior palatability (Nunes et al., 2019). But crucially, final body weight, growth, yield and survival of shrimp fed with shrimp head meal were lower than those fed a krill meal diet. These findings underscore how feed attractability and palatability are key components, but alone will not make up for the poorer nutritional quality of other marine feeds.

### Krill - a biochemical power boost

Many feed attractants play a dual role and simultaneously, for example, stimulate the immune systems. Chitin is one such component. The fibrous substance is constructed from polysaccharides and forms a protective outer layer

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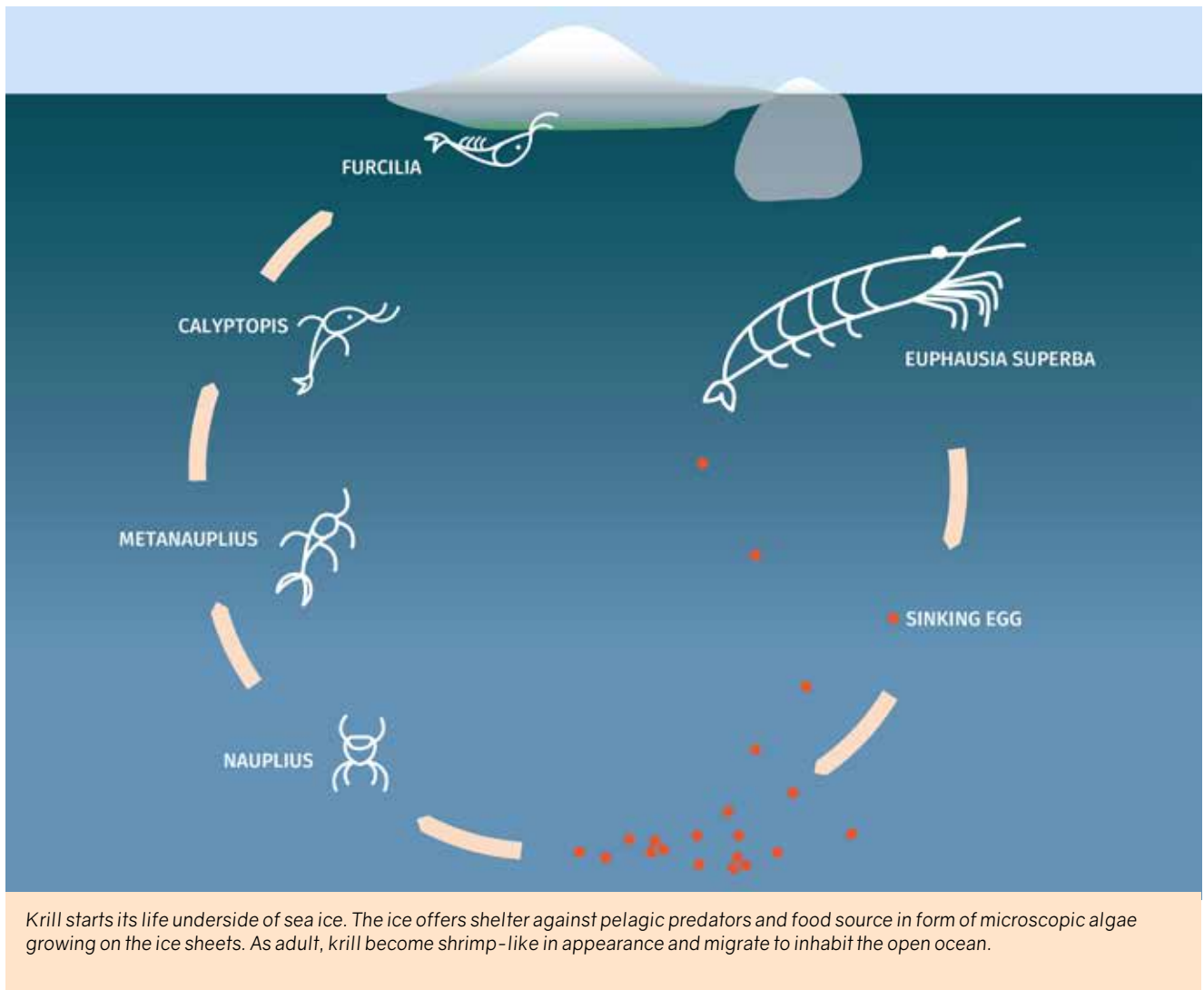
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of the krill's exoskeleton. In white shrimp, chitin-injected individuals were more immunocompetent and resisted *Vibrio* bacterial infection more easily (Wang & Chen, 2005). Similarly, chitin has been shown to improve the immune system of seabream, particularly the innate cellular immune system, through modulating head-kidney leucocyte activity (Esteban et al., 2000; Cuesta et al., 2003).

Similarly, the antioxidant astaxanthin, a pigment that gives krill, but also salmon or flamingos, its red colouration, has anti-inflammatory properties. In algae, from where the carotenoid pigment originates, it protects its maker from environmental stress. It is therefore unsurprising that the inclusion of astaxanthin krill oil in the diet of *L. vannamei* allowed the shrimp to cope better with osmotic and thermal stress (Nunes et al., 2020).

Krill also contains essential vitamins, such as vitamin A, D and E. Vitamins are macronutrients that like oil in a machine functions to optimise metabolic processes. Stress can cause the denaturation of fatty acids, which as free radicals then disrupt and break other polyunsaturated fatty acids embedded in cellular structures such as the cell

wall. This causes tissue damage, which hinders growth, reduces survival and lowers product quality, especially during early development.

Therefore, it is the combination of a rich protein and lipid profile mixed with chitin, astaxanthin, dietary phospholipids, vitamins and other low molecular weight soluble attractants that make krill meal an ideal feed component to improve production and cope with stressful farming conditions while improving animal well-being and farming sustainability.

References are available on request



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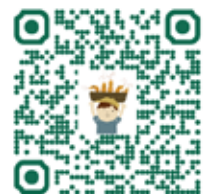


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# Partial to total substitution of fishmeal with methanotroph bacteria meal in Pacific white shrimp diets

Improvements range from growth performance and survival rate to the ability to tolerate an AHPND/EMS challenge

By Orapint Jintasatoporn, Srinoy Chumkam, Supawit Triwutanon, Allan LeBlanc and Jarin Sawanboonchun

Fishmeal is a major protein source in shrimp diets. However, it can be an expensive ingredient because of high demand and inelastic supply (Samocha et al., 2004) and thus one option for feed mills is to substitute fishmeal with alternative proteins, but these frequently do not meet the nutritional requirements of shrimp and can have variable or unbalanced nutritional profiles (Malcorps et al., 2019). Alternative protein meals include those from plant and animal sources as well as single cell proteins (SCPs) such as yeast, fungi, microalgae and bacteria. The application of single-cell ingredients in aquaculture feeds was recently reviewed by Glencross et al. (2020).

Acute hepatopancreatic necrosis disease (AHPND), also known as early mortality syndrome (EMS), is a major concern affecting shrimp production. It is caused by *Vibrio parahaemolyticus* with outbreaks occurring routinely in Southeast Asia shrimp farms in which mortality rates exceed 70% and global annual losses are estimated at more than USD1 billion (Zorriehzahra and Banaederakhshan, 2015). *V. parahaemolyticus* is transmitted orally and infects the digestive organs and hepatopancreas of shrimp (Lightner et al., 2012).

## Single cell proteins

Methanotrophs are gram-negative bacteria that use methane as their sole source of carbon and energy, and have been identified for their potential use as a protein source in feeds for a variety of aquaculture species (Berge et al., 2005; Øverland et al., 2006; Aas et al., 2007; Øverland et al., 2011; Biswas et al., 2020; Chen et al., 2021). However, to date only one published study has evaluated the use of *Methylococcus capsulatus* as an alternative protein source for shrimp feed formulations with up to 45% of the fishmeal replaced with FeedKind® followed by exposure to *V. parahaemolyticus* by intraperitoneal injection (Chen et al., 2021). He reported that replacement of fishmeal with methanotroph bacteria meal did not negatively impact growth or feed conversion rates of shrimp. He also found that at higher dietary levels, shrimp experienced increased oxidation levels in the hepatopancreas, increased height of the mucosal folds in the gut, improved gut microbiota and increased resistance to a *V. parahaemolyticus* challenge.

Building on the results obtained by Chen et al. (2021), we conducted a study at the Nutrition and Aquafeed Laboratory, Department of Aquaculture, Faculty of Fisheries, Kasetsart University, Bangkok, Thailand. The trial investigated the efficacy of FeedKind® (Calysta, Menlo Park, USA) in diets on growth performance and feed efficiency of the Pacific white shrimp *Penaeus vannamei* while also assessing its impact on animal health during a *Vibrio* challenge.

This 71% crude protein methanotroph bacteria meal (*Methylococcus capsulatus*) has been shown to be a viable protein source for popular species of aquaculture fish including rainbow trout (*Oncorhynchus mykiss*), Atlantic

salmon (*Salmo salar*) and yellowtail (*Seriola quinqueradiata*) (Berge et al., 2005; Øverland et al., 2006; Biswas et al., 2020).

An additional benefit of producing methanotroph bacteria meal, is that it utilises less than 0.01% of land and around 10% of blue water compared with that used to produce soy protein, thus enhancing aquaculture's sustainability credentials.

Since this SCP is an inactivated gram-negative bacterial biomass, we hypothesized that it may impart an immune response in shrimp. Therefore, we investigated its effects on the survival rate and disease resistance of this shrimp in a disease challenge against *V. parahaemolyticus*, the causative agent for AHPND/EMS. In this article, we present some results from these trials. More details are available at: 10.3389/fmars.2021.764042

## Experimental design

Feed ingredients (Table 1) were ground to 150–250µm and then mixed, with 25% water added. The mixture was pelletised with a Hobart mincer. Pellets were dried at 60°C for 8–10 hours. All diets were sieved to a particle size range of 1.5–2mm for use in the trial. Soybean and poultry meal levels were adjusted accordingly to ensure crude protein levels were equivalent across all treatments.

A completely randomised design (CRD) was used for the growth trial with four treatments and five replicates. Diet T1 was a fishmeal-based control containing 15% fishmeal. Three treatment diets had graded levels of methanotroph bacteria meal (FeedKind) replacing fishmeal. Diet T2 - 5% methanotroph bacteria meal, replacing 33% of the fishmeal; Diet T3 - 10% methanotroph bacteria meal, replacing 66% of the fishmeal and Diet T4 - 15% methanotroph bacteria meal replacing 100% of the fishmeal.



Experimental tanks

Ingredients	Treatment diets			
	T1: Control	T2: FK 5%	T3: FK 10%	T4: FK 15%
Fishmeal, SE Asia, 64% CP	15.0	10.0	5.0	0.0
Methanotroph bacteria meal (FeedKind®), 71% CP	0.0	5.0	10.0	15.0
Krill meal, 54% CP	2.0	2.0	2.0	2.0
Squid liver meal, 43% CP	5.0	5.0	5.0	5.0
Poultry meal, 63% CP	5.0	5.0	5.0	4.4
Soybean meal (US), 48% CP	28.2	28.2	29.0	29.3
Soybean meal fermented, 53% CP	6.0	6.0	5.0	4.7
Wheat gluten meal, 78% CP	1.0	0.4	0.0	0.0
Wheat flour	26.3	27.0	27.7	28.5
Fish oil	1.2	1.2	1.2	1.3
Soybean oil	1.0	1.0	1.0	1.0
Soy lecithin	1.7	1.5	1.4	1.2
Vitamin premix <sup>1</sup>	2.0	2.0	2.0	2.0
DL-Methionine	0.2	0.2	0.2	0.2
Mineral premix <sup>2</sup>	2.5	2.5	2.5	2.5
Mono calcium phosphate, MCP	0.5	0.5	0.5	0.5
Tuna Hydrolysate	2.0	2.0	2.0	2.0
Polymethylcarbamide	0.5	0.5	0.5	0.5
Total (%)	100	100	100	100
<b>Proximate composition by AOAC (2000)</b>				
Moisture (%)	3.77	3.77	3.36	3.60
Ash (%)	9.60	8.94	8.78	8.32
Crude protein (%)	38.35	38.64	38.70	38.77
Lipid (%)	7.60	7.31	6.97	6.63
Calcium (%)	1.66	1.48	1.28	1.10
Phosphorus (%)	1.12	1.08	1.06	0.98
Fiber (%)	5.54	5.73	6.20	6.38
Energy (MJ/Kg)	19.08	19.49	19.06	19.47

<sup>1</sup> Containing 3,500,000 IU Vitamin A, 1,500,000 IU Vitamin D3, 75g Vitamin E, 15g Vitamin K3, 12.5g Vitamin B1, 10g Vitamin B2, 12.5g Vitamin B6, 0.01g Vitamin B12, 50g Niacin, 40g Pantothenic acid, 0.5g Biotin, 5g Folic acid and 100g Vitamin C per kg. <sup>2</sup> Contains 12.5g copper, 15g iron, 15g manganese, 0.5g iodine, 0.1g cobalt, 50g zinc, 0.175g selenium per kg.

**Table 1.** Compositions of treatment diets expressed as percentages (where CP = crude protein).

Shrimp juveniles from a farm in the Samutsongkram province, Thailand were acclimated under trial conditions for 10 days and were fed three times daily with a commercial feed containing 35% crude protein followed by a further 7–8 days feeding with the trial diet prior to the start of the study. Five hundred shrimp (average initial weight 1.17±0.09g) were randomly allocated in batches of 25 to each of the 20 tanks of 500L capacity, containing 300L of water. The trial duration was 6 weeks for growth trial and 2 weeks for disease challenge.

The water exchange was 20% every 2 days. Water quality was maintained as follows: pH 7–8, dissolved oxygen (DO) > 5.0 mg/L, temperature 27–31°C, salinity 15–20 PSU, alkalinity >100 mg/L and ammonia <1.0 mg/L. All data were analysed by one-way ANOVA (analysis of variance). At the end of the 6-week trial, material was collected for histological analysis, immune measurements and *Vibrio* spp. counts were determined as described in the following paragraphs.



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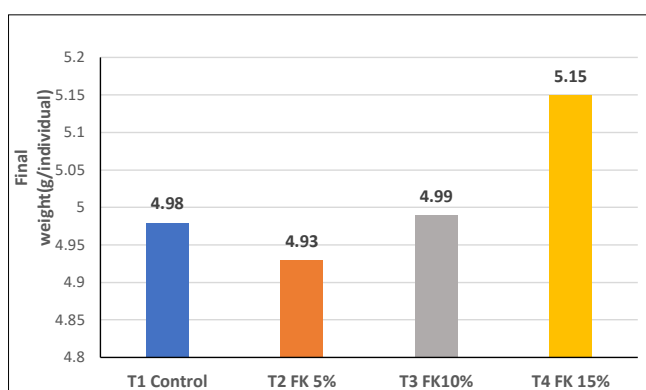
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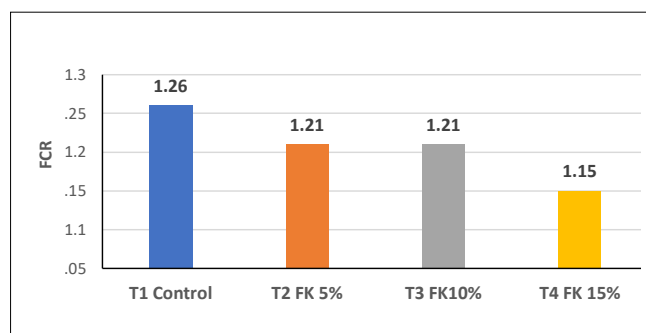
## Growth trials

The growth performance of white shrimp fed different levels of methanotroph bacteria meal for 6 weeks showed no significant differences ( $p>0.05$ ) in terms of final weight (Figure 1), weight gain, specific growth rate, feed consumption and feed conversion ratio (Figure 2) when compared to the control diet. Survival rate was not significantly different ( $p>0.05$ ) among treatments (Figure 3). These results confirmed prior studies (Chen et al., 2021) where FeedKind can replace up to 100% of fishmeal in white shrimp diets without any adverse effects on growth performance, feed utilisation and survival rate.

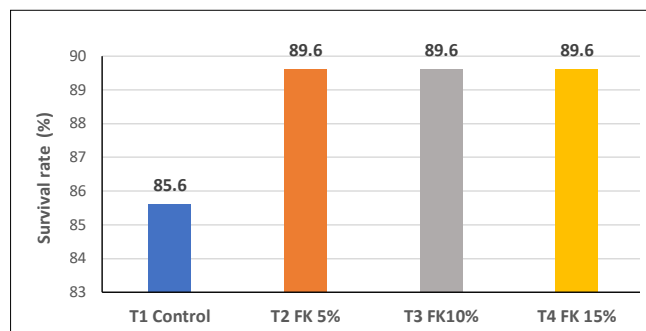
A study on single cell protein as replacement of fishmeal in shrimp diets has shown they can be used to replace fishmeal, partially or fully, e.g., purple non-sulphur bacteria (Chumpol et al., 2018), *Corynebacterium ammoniagenes* (Hamidoghli et al., 2019) and KnipBio meal (Tlustý et al., 2017).



**Figure 1.** Final weight (g) of white shrimp *Penaeus vannamei* fed control and treatment diets containing methanotroph bacteria meal (FeedKind®) for 6 weeks.



**Figure 2.** Feed conversion ratio (FCR) of white shrimp *Penaeus vannamei* fed control and treatment diets containing methanotroph bacteria meal (FeedKind®) for 6 weeks.



**Figure 3.** Survival (%) of white shrimp *Penaeus vannamei* fed control and treatment diets containing methanotroph bacteria meal (FeedKind®) for 6 weeks.

## Immune Parameters

The haemolymph of 50 shrimp per experimental treatment (10 shrimp per replicate) were randomly selected at the end of the growth trial and all shrimp per treatment at the end of the *V. parahaemolyticus* trial were collected using 10% (w/v) sodium citrate as an anticoagulant. The haemolymph were taken from the pericardial cavity using a 1-mL syringe, pooled and stored at  $-20^{\circ}\text{C}$  until analysis.

Table 2 shows no significant differences ( $p>0.05$ ) in haemocyte counts, haemolymph protein, phenoloxidase activity, lysozyme activity, superoxide dismutase activity and amount of total glutathione between treatments. However, *Vibrio* sp. counts in the haemolymph and in the hepatopancreas following plate cultures were significantly reduced in shrimp fed methanotroph bacteria meal compared with control diet prior to challenge with *V. parahaemolyticus*.

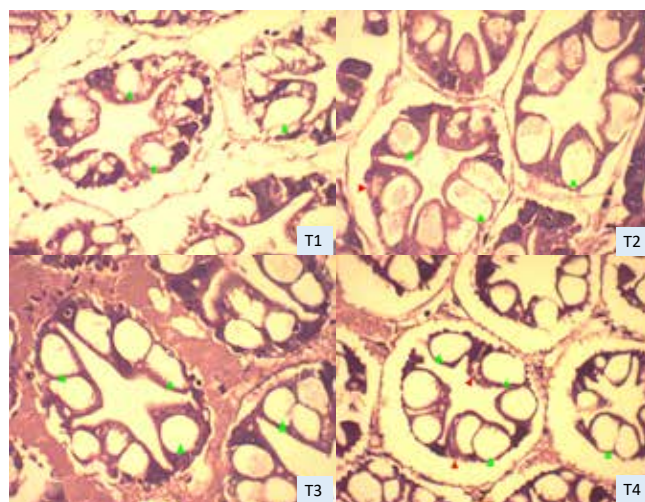
## Histology

Histological examinations of hepatopancreas health were conducted using five shrimp from each tank (replicate) in the growth trial. Small portions of hepatopancreas tissue were prepared according to the method by Bell and Lightner (1988).

Figure 4 showed that in shrimp fed treatment diets, blister-like cell (B-cell) percentage was highest in shrimp fed diet T2 (5% FeedKind) but lowest in those fed the control diet. Resorptive-cell (R-cell) percentages were highest in shrimp fed the control diet and in shrimp fed diet T4 (15% FeedKind) indicating improved nutrient storage capacity and nutrient accumulation to defend the shrimp from severe EMS disease challenge conditions. B-cell size was largest in the control group compared to other groups. Degeneration and change of lumen structure (note the star-like shape is normal) were found in groups fed diets T2 and T3 in which 33 and 66%, respectively, of the fishmeal was replaced with methanotroph bacteria meal.

## AHPND challenge

After 6 weeks, a total of 120 shrimp (30 shrimp from each treatment in the growth trial) were transferred to 100L aquariums for the challenge trial. There were three replicates, each with 10 shrimp/diet.



**Figure 4.** Light micrograph of hepatopancreas of shrimp fed different concentrations of methanotroph bacteria meal for 6 weeks under pre-challenge conditions (T1: Control diet, T2: FeedKind 5%, T3: FeedKind 10%, T4: FeedKind 15%; green arrow = B-cell, red arrow = R-cell; scale bar = 10 mm,  $\times 400$ ).

	T1: Control	T2: FK 5%	T3: FK 10%	T4: FK 15%	P-value
Haemocyte count ( $\times 10^5$ cell/mL)	25.40 $\pm$ 2.97	24.80 $\pm$ 2.77	26.40 $\pm$ 3.05	25.60 $\pm$ 3.36	0.87
Haemolymph protein (mg/dL)	4.64 $\pm$ 0.95	5.32 $\pm$ 0.59	5.36 $\pm$ 0.82	5.72 $\pm$ 1.39	0.395
Phenoloxidase activity (unit/min/mg protein)	56.24 $\pm$ 14.68	40.41 $\pm$ 7.93	50.89 $\pm$ 20.91	51.73 $\pm$ 14.62	0.435
Lysozyme activity (unit/ml)	403.33 $\pm$ 25.17	370.00 $\pm$ 72.11	370.00 $\pm$ 10.00	383.33 $\pm$ 40.41	0.761
Superoxide dismutase activity (unit/mL)	26.13 $\pm$ 3.13	25.95 $\pm$ 2.38	26.37 $\pm$ 3.78	23.92 $\pm$ 3.00	0.753
Glutathione (nM/mL)	37.83 $\pm$ 4.20	35.03 $\pm$ 1.80	36.90 $\pm$ 1.40	41.57 $\pm$ 6.07	0.284
<i>Vibrio</i> bacterial counts from hepatopancreas (Log CFU/mL)	2.61 $\pm$ 0.31a	2.39 $\pm$ 0.32a	1.16 $\pm$ 0.28b	1.38 $\pm$ 0.66b	0.001

Values with different superscript letters in row indicate significant differences ( $p < 0.05$ ) between treatments.

**Table 2.** Immune parameters (n = 10 per replicate) and *Vibrio* counts (n = 2 per replicate) of white shrimp *Penaeus vannamei* fed different levels of methanotroph bacteria meal for 6 weeks under pre-challenge conditions.

The *V. parahaemolyticus* (AHPND) virulent strain from the Faculty of Veterinary Medicine, Kasetsart University was cultured on tryptic soy agar (Difco) supplemented with 1.5% NaCl (w/v) for 24h at 35°C. After 24 h of growth, bacterial colonies were transferred to tryptic soy broth (Difco) supplemented with 1.5% NaCl and incubated for 24h at 35°C. Next, the bacterial culture was centrifuged at 1,000 rpm for 15 min at room temperature. The supernatant was removed and the bacterial pellet was resuspended in saline solution and then added to the tanks on Day 0 to reach a concentration of  $5.8 \times 10^4$  CFU/mL in the water column of each challenge test aquarium. The concentration used was based on prior results obtained in our laboratory for this strain. A negative control (unchallenged) group was included in the study. Challenged shrimp were immersed in the *Vibrio* solution and continued to be fed test diets for 15 days before termination when haemolymph was taken for immune measurements and hepatopancreas taken for *V. parahaemolyticus* assessment.



White shrimp *Penaeus vannamei* fed diets with different levels of FeedKind® for 6 weeks under normal conditions



White shrimp *Penaeus vannamei* fed diets with different levels of FeedKind® for 6 weeks under normal conditions then immersion by *Vibrio parahaemolyticus*  $5.8 \times 10^4$  CFU/mL.

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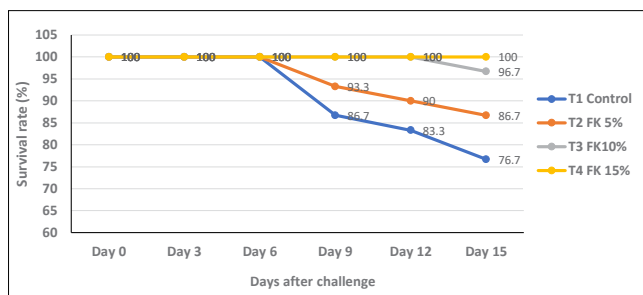
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### Survival rates

Post immersion challenge, no mortality was observed in shrimp fed diets containing 15% methanotroph bacteria meal, while only 76% of shrimp fed T1 diet (control) survived. Mortalities were noted in the control (T1) diet group from day 9 post-infection. The results showed that on day 9 to day 15 after immersion, shrimp fed the methanotroph bacteria meal at 10 and 15% in diets T3 and T4 had significantly higher survival rates ( $p < 0.05$ ) than diets T2 and T1 (control), respectively.

Chen et al., 2021 also reported reductions in mortality in shrimp that were fed a diet containing FeedKind during a challenge with *V. parahaemolyticus* by injection compared to shrimp fed control diets without bacterial meal. These results largely agree with the current study and differences in survival rates can be partly explained by challenge method (IP vs. bath) and challenge dose.



**Figure 5.** The survival rate of shrimp following immersion challenges by *Vibrio parahaemolyticus* (AHPND) at  $5.8 \times 10^4$  CFU/mL for 15 days after being fed feeds containing different levels of FeedKind® for 6 weeks.

### Post-challenge immune parameters

The measured immune parameters of post-challenged white shrimp collected after 15 days are given in Table 3. Haemocyte count and phenoloxidase activity showed no significant differences ( $p > 0.05$ ) between diet treatment groups, but haemolymph protein was significantly higher ( $p < 0.05$ ) in shrimp fed diet T4 with 15% methanotroph bacteria meal.

The *Vibrio* colony counts from hepatopancreas in the treatment groups were all significantly lower than the control ( $p < 0.05$ ) and the colony counts from the group fed diet T4 were further reduced and significantly different from diet T2.

	T1: Control	T2: FK 5%	T3: FK 10%	T4: FK 15%	P-value
Haemocyte count ( $\times 10^5$ cell/mL)	12.67 $\pm$ 1.53 <sup>a</sup>	11.67 $\pm$ 2.08 <sup>a</sup>	13.00 $\pm$ 3.00 <sup>a</sup>	16.33 $\pm$ 3.79 <sup>a</sup>	0.256
Haemolymph protein (mg/dL)	4.00 $\pm$ 1.21 <sup>b</sup>	4.13 $\pm$ 0.55 <sup>b</sup>	4.15 $\pm$ 0.44 <sup>b</sup>	6.76 $\pm$ 0.37 <sup>a</sup>	0.004
Phenoloxidase activity (unit/min/mg protein)	23.14 $\pm$ 10.10 <sup>a</sup>	24.42 $\pm$ 3.14 <sup>a</sup>	24.72 $\pm$ 6.04 <sup>a</sup>	20.84 $\pm$ 0.83 <sup>a</sup>	0.859
<i>Vibrio</i> bacterial counts from hepatopancreas (Log CFU/mL)	3.70 $\pm$ 0.02 <sup>a</sup>	2.65 $\pm$ 0.17 <sup>b</sup>	2.13 $\pm$ 0.18 <sup>b</sup>	1.47 $\pm$ 0.82 <sup>c</sup>	0.001

Values with different superscript letters in a row indicate significant differences ( $p < 0.05$ ) between treatments.

**Table 3.** Immune parameters in white shrimp fed different levels of methanotroph bacteria meal after 15 days of immersion with *Vibrio parahaemolyticus*.

### Conclusion

Our findings showed that the methanotroph bacteria meal can entirely replace fishmeal in white shrimp diets. FeedKind can replace fishmeal at the levels of 33%, 66% and 100% (FeedKind at 5%, 10% and 15% of total feed) in white shrimp diets without any adverse effects on growth performance, immunity and survival rate. This study also indicated that the substitution of fishmeal with this SCP did not affect feed uptake, nor did it have effects such as antinutritional properties or impact a range of immune measures under experimental conditions. Additional studies are suggested to validate these results under field conditions.

The bacteria meal also reduces the presence of *Vibrio* in hepatopancreas of experimental shrimp under normal conditions. When challenged with *V. parahaemolyticus*, shrimp in this study demonstrated an increased tolerance to disease, indicating that inclusion rates of 5-15% of FeedKind may help promote a robust immune response. Survival rates are corroborated by reduced *Vibrio* plate counts and enhanced haemolymph immune markers making this a very promising result.

References are available on request



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# Feed with impact

Startup INSEACT is targeting the shrimp feed market and in particular, farms in Southeast Asia

By Tim van Vliet

Almost all seafood is farmed and almost all farmed seafood uses wild-caught fish as the critical protein component of feed. With the demand for seafood products such as shrimp rising rapidly, the world's reliance on wild-caught fish, for its derivative - fishmeal, has increased exponentially over the last two decades.

INSEACT is changing this by reducing the industry's reliance on fish protein with insect protein. We are a Singapore-based company that grows black soldier fly (*Hermetia illucens*) larvae fed with waste from the palm oil industry that was otherwise destined for landfills. From the larvae we harvest and produce a high-quality protein meal which we have branded as XFprotein.

Applied as a protein ingredient in shrimp feed, we have witnessed significant improvements in feed conversion ratios (FCR), growth rates, as well as survival and disease mitigation. INSEACT is scaling up this alternative for global shrimp farmers but will initially target the farmers in Southeast Asia.

## How we came about

INSEACT was founded at INSEAD business school, where my co-founder, Michael and I, attended the MBA programme. The startup won both the INSEAD Venture Competition and Social Impact Award. Together we have a combined experience of 15+ years in food entrepreneurship and industrial scale-ups. I have also been fortunate to have worked at one of the world's largest insect protein companies. Since the early days in INSEAD, we have gone on to raise seed funding of USD1.3 million from reputable institutional investors, such as the Asian Development Bank, as well as family offices and VCs around the world.

## Targeting shrimp feed industry in Southeast Asia

XFprotein's unique application in shrimp feed performs better and more economically than traditional feed options. For a start, shrimp farmer's profits are boosted through the efficient use of this feed. This is due to a combination of factors.

First and foremost, our laboratory trials have shown XFprotein yields a 21% improvement in FCR, allowing farmers to save on feed costs per cycle. In addition, using this novel ingredient in shrimp feed also results in an increased growth rate of as much as 18%. Finally, shrimp health and disease-resistance have also seen a resultant improvement largely due to the presence of anti-microbial peptides, high amounts of lauric acid and, most significantly, chitin - a fibrous substance consisting of polysaccharides, the major constituent in the exoskeleton of arthropods such as shrimp. Our lab trials have shown that disease mortality is 45% lower when shrimp were fed XFprotein. Most importantly, though shrimp love the product with the insect meal as an effective attractant in the feed.

Our desire is to increase profitability for the shrimp-farming community, beginning with farmers in Southeast Asia. To achieve this, our team has already begun collaborations

**“While working with us, palm oil mills can reduce their environmental impact whilst gaining new revenue streams.”**

with several shrimp feed manufacturers and rapidly bring its products to eager customers across the region.

Working with Singapore Food Agency's Marine Aquaculture Centre on St John's Island, we have already produced an initial batch of our shrimp feed with insect protein inclusion. Further laboratory tests with the new shrimp feed formula are also ongoing at the Aquaculture Innovation Centre in Temasek Polytechnic, with large-scale commercial trials with the Lim Shrimp Organisation later this year. The latter operates some of the largest shrimp farms globally.

In addition to boosting profitability for shrimp farmers, we also want to bring a positive impact to the environment by being carbon-negative in our operations. Both are achieved through highly efficient insect farming, made further impactful through the choice of feedstock. The palm oil waste that is used as feedstock for our larvae not only needs to be disposed of by the mills but also results in significant amounts of methane emissions.



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Our carbon-negative solution diverts this waste away from landfills, upcycling it as feedstock for BSF production. This is why Southeast Asia was the obvious choice for us to base INSEACT in – having unfettered access to a feedstock supply that is available in large quantities in the region and at a low cost. While working with us, palm oil mills can reduce their environmental impact whilst gaining new revenue streams.

### Scalability and availability

Finally, as a relatively young member of the insect farming community, we understand that scalability and the availability of large volumes of insect meal are some of the main problems faced by the industry. The unavailability of consistent and high-quality supply has been one of the key reasons aquafeed manufacturers have not been able to incorporate insect meal into their products at scale.

We have found a way to solve this problem through our modular and breakthrough insect farming technology. Coupling advanced technology with the availability of our chosen feedstock in the region, the company can supply large volumes of BSF meal that is consistent and of high quality.

### Laying the foundation for its industrial scale-up

Within a year and a half, we have built a team comprising domain experts who are passionate, smart and driven. Motivated by the common desire to do well by doing good, we are nimble, resourceful, and determined to overcome the challenges that arise from our shared mission.

Just eight weeks into receiving the keys to our facility at Cleantech One, we currently run a fully operational state-of-the-art pilot facility applying technology adopted from best practices across various sectors, together with the latest in insect farming technology, to re-imagine what

industrial-scale production could look like in BSF farming. This facility has been specially designed to be modular with an initial production capacity of 1,000 tonnes of protein annually; it will be the prototype for numerous regional sites, each with the ability to produce 10,000 tonnes annually. With that in mind, 2022 will see us raising a Series A round of funding to scale production operations in Malaysia whilst growing our support and business functions in our Singapore headquarters.

### Building bridges

To achieve our mission, the team also spends much of our time building lasting relationships with partners, stakeholders, and legislative authorities across Southeast Asia, as well as the globe.

Our aim is to secure feedstock supply for our BSF farms by working closely with palm oil mills in Malaysia and Indonesia, which collectively form the supply of more than 80% of the world's palm oil. These partnerships will enable us to have the feedstock we need to produce our target of at least 100,000 tonnes of BSF protein annually by 2028. With these volumes, we would be able to scale the positive impacts of BSF meal as a protein and nutrient component in shrimp feed and bring about greater profitability to shrimp farmers. While being laser-focused on this goal, we also remain open to exploring other markets and business lines across areas such as ornamental aquafeeds, insect oil, and organic fertilisers.

As founders, we understand that the insect protein industry is still very much in its nascent stage, where collaboration and cooperation are critical to the future of the industry and the resultant ability of insect-farming companies to bring about change into the world. We continue to build a strong alliance with shrimp farmers, feed mills, aquaculture experts, palm oil mills, government bodies, and even other black soldier fly companies. We believe that teamwork is what will make our dream work.



Tim van Vliet (left) is CEO and Michael Badeski (right) is COO of the insect protein startup INSEACT which they started when attending the MBA programme at INSEAD. In 2019, INSEACT won the INSEAD Venture Competition and the Social Impact Award.

# The New Blue is Green

Aqu@Event by Adisseo sharing new insights on the use of novel technologies to improve the sustainability and climate resilience of aquaculture

The second edition of the Aqu@Event by Adisseo took place on 23 November 2021 combining an online webinar with a booth platform. Under the theme “The New Blue is Green,” five experts shared their insights on the use of novel technologies to improve the sustainability and climate resilience of aquaculture. The talks were subtitled and followed by a live panel discussion.

**Gorjan Nikolik** from Rabobank International has been following the insect meal production industry for the last 15 years. He gave an interesting global outlook and economic reality of insect protein production titled “No longer crawling: Insect protein to come of age in the 2020s”. “From replacing fishmeal with plant meals, we really need to focus on sustainable ingredients, with the right protein content. There are three platforms developing products: algae for omega 3s, microbial for single cell protein and insect meals.” But he added that it does not mean that insect meals are going to replace fishmeal and fish oil- it just means that they will play a role together with other ingredients.



**Figure 1.** Insects as a circular economy solution (Source: No longer crawling: Insect protein to come of age in the 2020s, Gorjan Nikolik, Rabobank International.)

Insect meal is a circular economy solution to the global protein challenge, using waste streams from pre consumption wastes. “Insects have the potential to bring new value-added propositions, with nutritional, functional and environmental benefits. Circularity is combined with a potential and large long term market size,” said Nikolik. “There are many players entering this space over the last 15 years. Good market opportunities have attracted passionate entrepreneurs across Europe and Asia. Industry is still at the entrepreneurial phase; we still do not see a domination by large corporations. Funding has been accelerating and 2020 was a big year with one player securing 60-70% of funds. The legislation in Europe is improving and giving these companies a boost. Many are now in the construction phase heading towards commercial scale production.”

Nikolik noted three limitations. Production is limited whereas feed industry needs bulk. Current costs are high relative to price levels and current legislations. The global aquafeed market is almost 42 million tonnes and global insect meal production is currently at less than 10,000 tonnes. “The current volume is insufficient to run full-fledged trials. In our interviews with users, the latter said

that they struggle to find enough to run proper testing. They need consistent supply of 4,000 to 5,000 tonnes per year. Within 4-5 years, with the commercial plants up and running, we expect this issue to be resolved.”



Gorjan Nikolik said, “Insect meals should be used for the performance that it brings,”

Price is still high, and many users have commented on why this is so, when compared to the price of fishmeal which is a limiting resource. “So, the point is that without a very competitive price, insect protein has to find a different use in the feed formula- it will not be easy to replace fishmeal and soyabean meal. Insect meals should be used for the performance that it brings. The industry is still researching on how to best position itself. Legislation will not be a barrier for long.”

In August 2021, the European Commission approved insect meals for poultry and swine feeds. Nikolik added that another step is for more substrates such as meat and fish processing waste to be used as raw materials for insect production.

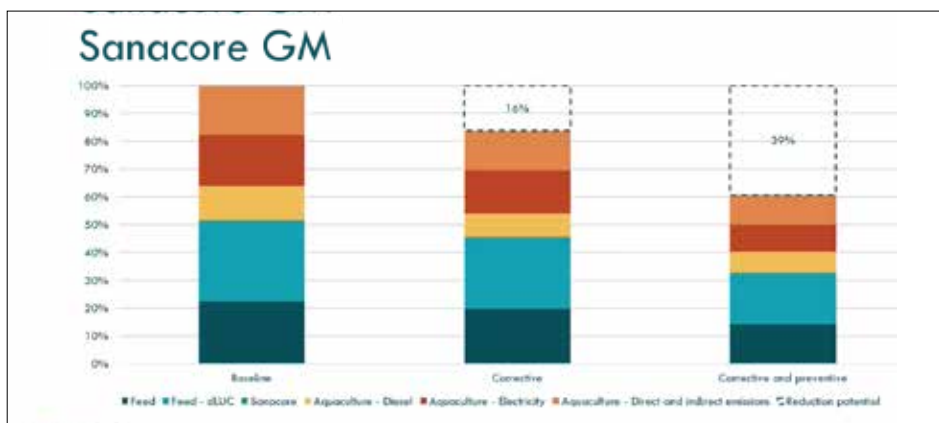
To assess the demand, interviews with buyers and producers of insect proteins indicated that industry reaches maturity in 10 years and when prices are €1,500-2,500/tonne, production can reach 0.5 million tonnes, with aquaculture and premium pet food as major users.

On demand from the aquafeed industry, he said, “Most aquafeed formulators are aware that insect proteins have nutritional benefits and are keen on their sustainability credentials. Research is ongoing to understand how they bring value but also where impact is highest and for which species.

Nikolik concluded, “Scale is coming, and Rabobank is enthusiastic. The bank focuses on equity and is a lender for one company. The upside is good but although there is very good science, R&D needs to demonstrate benefits beyond the good nutritional value.”

## LCA of specialty feed additives

Blonk Consultants, represented by **Bjorn Kok**, is a Dutch company specializing on sustainability and life cycle assessments (LCA) in the agri-food sector. Kok explained the basics on quantifying sustainability in aquaculture and illustrated this with a few demo cases showing the potential of Adisseo’s specialty feed additives to mitigate the environmental impacts from aquaculture.



**Figure 2.** Blonk Consultants showed up to 39% improvement of the environmental footprint in aquaculture production with the application of Adisseo's Sanacore GM in the presentation on potential impact of feed additives on LCA of aquafeed/aquaculture.

Kok introduced the challenges with LCA analyses, "Why do we care about sustainability of our food production? It is a major contributor to environmental impacts. A quarter of GHG emissions is occupied by food production and 70% of freshwater is used for agriculture. Some 80% of freshwater pollution is due to agriculture. Increasingly there is the sustainability demand from consumers, leading to world-wide scale adoption of eco labelling." He added that many consumers find it difficult to gauge which products are environmentally friendly.



*Bjorn Kok says that LCA is an operational tool to measure how sustainable systems are. It is a multicriteria method to qualify all environmental impacts along the life cycle of products and identify environmental hotspots.*

Therefore, the European Commission (EU) came up with green claims/green deal and PEF (Product Environment Footprint) initiatives. The EU commission wants companies making green claims to substantiate them against a standardised methodology, the LCA analysis. This is an operational tool to measure how sustainable systems are. It is a multicriteria method to qualify all environmental impacts along the life cycle of products and identify environmental hotspots. Kok explained that there are limitations to LCA, from quality of data which is separated among various segments in the supply chain. Collection of these data is also a challenge which leads to some statistical uncertainty. While the complexity of multicriteria is difficult to communicate to consumers, there is also a potential misuse of LCA in terms of cherry-picking methodologies leading to misleading claims.

In the LCA on Adisseo's feed additives, he explained the goal and scope of the project and how the feed additive affects the life cycle perspectives – from changes in feed composition, improvement in feed conversion efficiency, reduction in losses to direct mitigation of environmental emissions. "We did a cradle to aquaculture farm gate assessment with the functional unit of 1kg shrimp. Data from feed trials were used. For growth, we use farm activities including assessments on water and aeration management, and emission models for nitrogen and phosphorous flows. The result of this LCA is a strong mitigation potential in terms of carbon footprint; for Aqualyso, 7-20% and for Sanacore, 16-39%."

## Coping with climate change

Professor **Chris Carter** from IMAS (Institute for Marine and Antarctic Studies (IMAS) University of Tasmania – Australia) discussed the relevance of thermal stress on aquafeed formulations, an area which will require more attention to cope with more extreme climate conditions. He focused on the challenges that relate to feeding and nutrition, and the responses being put forward. Temperature can be considered as the most important overriding factor influencing the aquatic ectotherms. "Both the number and severity of high and low temperature events are expected to increase. These are important considerations when we think about nutritional interventions," said Carter.



*The potential for nutritional intervention is at various stages, before and during suboptimal temperatures and environmental conditions and during the recovery phase, says Professor Chris Carter.*

The Asian seabass is robust, performing very well across a wide temperature range, from 21 to 39°C, measured in terms of feed intake, specific growth rate (SGR) protein productive value (PPV) and energy efficiency (PEV). SGR and PPV predicted an optimum temperature of 31°C. However, he said that thermal stress impacts the Atlantic salmon in Tasmania over a narrow temperature range; good growth is demonstrated at around 19°C when dissolved oxygen (DO) is 100% but not when DO is low. The temperature range is small from 16.5 to 17.5°C. "The potential for nutritional intervention is at various stages, before and during suboptimal temperatures and environmental conditions and during the recovery phase," added Carter.

## Microbiome and gut health

Professor **Han-Ching Wang**, National Cheng Kung University and National Centre for the Development of Shrimp Aquaculture, Taiwan, explained the significance of microbiome and gut health for shrimp producers, a promising area for improving shrimp's resilience to disease outbreaks and for a more sustainable production.

In discussing the resilience of the gut microbiome, Wang said that the microbiome state is very dynamic, shifting from (or between) healthy and unhealthy states,



On microbiome and gut health for shrimp producers, Professor Han-Ching Wang says this is a promising area to improve shrimp resilience to disease outbreaks and for a more sustainable production.

intermediate unstable and unhealthy states. “We can intervene at the unstable state with good gut development with diet etc. Otherwise, it will lead to dysbiosis which is the loss of beneficial microbes, expansion of pathobionts and loss of bacterial diversity. The effect is the alteration of nutrient availability to host and stomach bacteria impacting the metabolic function.”

Wang showed how the microbiota balance is disrupted during an acute hepatopancreatic necrosis disease (AHPND) outbreak with a discussion on the interplay of key factors – microbiota, stomach metabolism, biofilm function, peritrophic membrane, cuticle, immune factors, epithelial cells and the hepatopancreas.

With sampling shrimp cultured in outdoor grow-out ponds and affected by AHPND at 36 days post stocking, she said, “Microbiota profile between AHPND affected shrimp and healthy shrimp were different. The microbial diversity in diseased shrimp suddenly declines. However, some shrimp maintained microbial balance even after environmental stress or when cultured with diseased shrimp.”

There are also *Vibrio* related interactions in the stomach of healthy and diseased shrimp. “In diseased shrimp the hub is played by *Vibrio* spp but in healthy shrimp, this is played by Lactobacillales which suppressed the growth of *Vibrio* spp. This is evidence for a potential probiotic to suppress AHPND outbreaks.” Dysbiosis occurs in AHPND infected shrimp and from her investigations on metabolite effects, she identified 1,100 significantly changed metabolites related to lipid metabolism. “These metabolites engage in biosynthesis of unsaturated fatty acids, bile acids and fatty acids”.

Wang summarised that gut health is related to more than digestion and absorption. It is important that shrimp maintain a healthy gut microbiota balance, physical barriers, immune responses, and a healthy diet. It is also important to select and breed shrimp with genetics shaping the healthy gut microbiome.

### Alternative protein sources for shrimp feeds

Professor **D. Allen Davis** from the School of Fisheries, Aquaculture and Aquatic Sciences, Auburn University, USA shared his experiences on evaluating alternative protein sources in shrimp feeds with emphasis on novel plant proteins. This is on re balancing nutrition and sustainability. Davis reminded the audience that there is no nutritional requirement for ingredients.

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"When we replace ingredients, we are shifting the nutrient profile and we need to find other ingredients that will bring in those nutrients."

- D. Allen Davis

"When we replace ingredients, we are shifting the nutrient profile and we need to find other ingredients that will bring in those nutrients. We also need to consider processing since we may change feed characteristics. For example, we can use 40% distiller's dried grains with solubles (DDGS) yet from a processing standpoint we cannot go beyond around 30%. Palatability is important and we need to have bioactive compounds."


He added that room in the formulation is often limiting. "Therefore, we may need high protein ingredients especially for a high protein diet. When problems arise, a systematic approach can produce good results."

As fishmeal is a dense nutrient, he discussed the balancing of amino acids in the blending of complimentary ingredients. Studies showed no significant difference in the performance of shrimp fed different levels of fishmeal and fermented corn protein concentrate (FCPC). There was only zeaxanthin, but shrimp converted them to astaxanthin to give the red colouration. Davis discussed research where there were no differences in performance in shrimp fed high protein distillers' grains (DDG) replacing fishmeal or a novel bacterial biomass replacing soybean meal. With regards to algae-based products which are good sources of proteins and lipids, *Spirulina* seems to work well for many species. "Interestingly, with *Ulva* meal, research with three products shows low inclusion levels worked but variability in these products could imply antinutrients and digestion issues," added Davis.

### Commitments on climate change


In their press release on this event, Adisseo said that at the COP26 Climate Change Conference in Glasgow, strong commitments were taken by world leaders towards securing global net zero carbon and keeping 1.5 degrees in reach. The urgent measures to tackle the climate crisis will soon have a drastic impact on our daily life and work. At the same time, all of us have great opportunities to contribute to reach the COP26 goals by working towards a more climate-resilient, sustainable aquaculture.

"The first LCA studies presented at this event by Blonk Consultants, showed up to 39% improvement of the environmental footprint in aquaculture production - thanks to the application of some of Adisseo's specialty additives. Specialised feed additives can significantly reduce the environmental impact and carbon footprint of aquaculture through multiple ways, including reformulating, using more sustainable ingredients, enhancing feed intake and digestive/metabolic efficiency, or simply improving survival thanks to a better health status of your fish or shrimp," says Dr Peter Coutheau, BU Director Aquaculture at Adisseo.




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# Influence of water temperature on induced reproduction of milkfish during the off-season

Manipulation of water temperatures allows the fish to spawn during colder months and is a goal towards consistent fry production throughout the year

By Dan D. Baliao, Roger Edward P. Mamauag and Leobert D. de la Pena



A milkfish harvest.

Milkfish (*Chanos chanos*) is one of the most important fish farmed commercially in the Philippines. The current production of 400,120 tonnes indicates an increasing trend in production. They are a hardy, fast-growing and euryhaline fish cultured throughout the Southeast Asian region, particularly in the Philippines, Indonesia and Taiwan (Emata & Marte, 1994). They mature and spawn after 5 years. In the Philippines, spawning occurs from March to November when the water temperature is above 30°C (Emata, 1993). Therefore, spawning is very limited during the colder water temperature months, from December to February (Figure 1).

## Conditions for spawning

Artificial induced spawning of milkfish broodstock can be done with an intramuscular injection or pellet implantation of hormones (i.e. salmon pituitary homogenate, SPH; human chorionic gonadotropin, HCG; luteinising hormone releasing hormone, LHRH-a; salmon gonadotropin releasing hormone, sGnRH-a). Spawning occurs after 16-32 hours post-treatment (Marte, 1988). However, hormone injection can elicit acute stress in fish, often leading to death.

Aside from the invasive hormone treatment, milkfish reproduction can be achieved through the manipulation of several environmental factors such as temperature and photoperiod. These conditions influence gonadal activity in fish by way of the hypothalamic-pituitary-gonad axis, which results in endocrine fluctuation (Crim, 1985). Environmental signals for the reproduction of fish vary according to the spawning season (summer or winter) and geographic locations (tropical, subtropical or temperate regions, Figure 2).

Milkfish has a wide geographic distribution from 40°E to about 100°W and 30-40°N to 30-40°S which covers the tropical and subtropical regions. Winans (1980) indicated the existence of genetically distinct populations of milkfish in waters off Hawaii, the Philippines and several Pacific Islands. However, Eguia et al. (2018) suggested that milkfish broodstock from Indonesia were similar to the Philippines' local wild-bred stocks based on genetic variability indices. Within the Philippines, samples are presently characterised by relatively high levels of genetic diversity. Thus, environmental factors for the maturation of milkfish may vary among these populations.

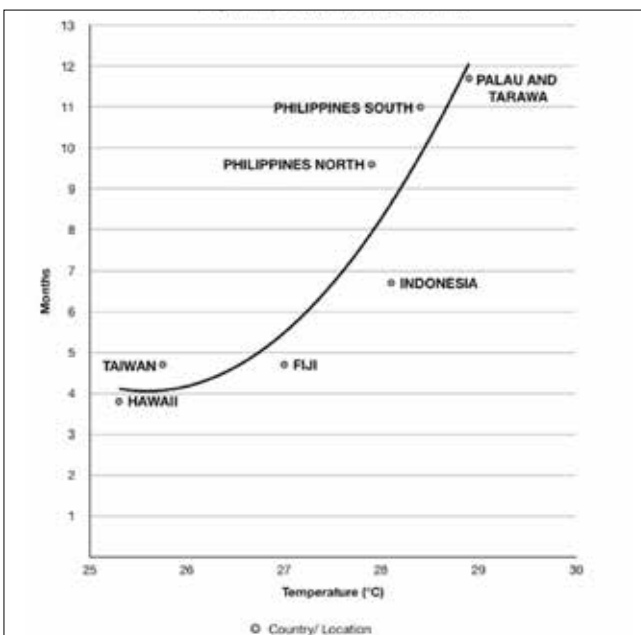
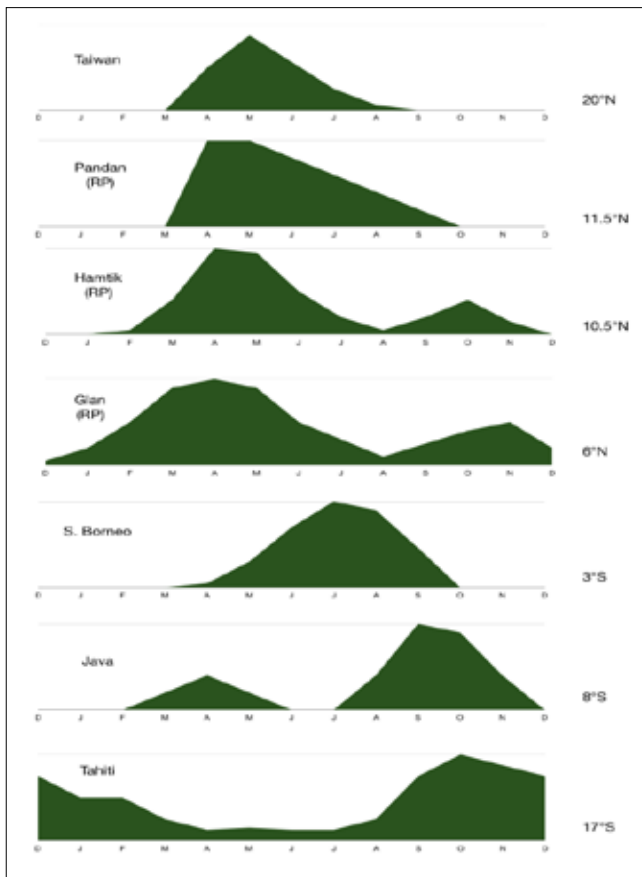


Figure 1. Correlation between mean and annual surface seawater temperature and length of fry season in various countries.



**Figure 2.** Milkfish spawning season cycle in different latitude locations.

### Temperature influences on spawning

Water temperature is one of the most critical environmental factors influencing the reproductive cycle of fish. Increasing water temperature induces early maturation of summer spawning species Northern whiting, *Silago sihama*. Meanwhile, the maturation of winter species such as mullet, *Mugil cephalus*, is triggered by a decrease in water temperature. Wainwright (1982) concluded that the fry season was dependent on the rising and falling of sea surface temperature. This implies that rapid gonadal development of milkfish is correlated with rising water temperature (Bagarinao, 1991).

The length of the fry season is correlated with the length of the spawning season. Fry caught along the coast (Philippines, Indonesia and Taiwan) were about 10-15 days old, suggesting that spawning season is two weeks earlier than the fry season. Wainwright (1982) indicated a correlation between fry season and the average annual surface seawater temperature (Figure 1). The area identified with a higher average surface water temperature has a longer fry and spawning season. At the end of the spawning season, gradual temperature decreases were observed in several locations. Collected data indicated that the milkfish fry season is longer in the southern hemisphere compared to the northern hemisphere (Kumagi, 1984) which further suggests that the water temperature influences the length of the spawning season. (Figure 2). Numerous research indicates that the minimum water temperature during the spawning season of milkfish is about 25°C (Wainwright, 1982; Lin, 1984) with an optimum water temperature range of 25-35°C (Bagarinao, 1991; Yap et al., 2007).

Photoperiod, associated with temperature, is another important environmental factor in fish reproduction. In general, winter spawning species need short light periods and summer spawning species need long light periods for initiating gonadal development. In milkfish, Lee et al. (1986) tried to initiate maturation by monitoring the photoperiod from 6L:18D to 12L:12D and to 18L:6D. The study concluded that 86% of the fish in the tank matured after three months under 18L:6D conditions.

Scientific studies on milkfish's induced spawning and larval rearing by increasing water temperature in tanks are very limited. In order to increase the production capacity of milkfish fingerlings, a preliminary experiment was conducted at the Southeast Asian Fisheries Development Center, Aquaculture Department (SEAFDEC/AQD). This study was on the effect of increased water temperature in milkfish broodstock and larval tanks during the cold and off-breeding season (October to February).

### Methodology

Milkfish broodstock of 4kg average body weight and average age of 25 years is currently maintained at the Integrated Milkfish Broodstock and Hatchery Complex. Milkfish broodstock feeding protocols and water management were observed during the duration of the experiment. Fish were fed with the SEAFDEC/AQD milkfish broodstock formulated diet (Reyes, 2000) at a feeding rate of 3-6% of the body weight. A flow-through water system was used to maintain the water depth and quality. Aeration lines were installed at strategic locations in the tanks.

Fifteen units of water heaters (BNH, 3kW 340V) were installed at the outlet of the sand filter box (Figure 3). At the onset of operation, temperatures from the water source, canal-intake (water supply) and in the broodstock tank, respectively, were calibrated to achieve the desired temperature of 30°C.

Airlift egg collectors were installed in the broodstock tanks every 1500h and the eggs were collected at 0700h the following day. The collected milkfish eggs were washed and placed inside the incubation tanks until hatching to larval stages.

Eggs and larvae were counted by taking a sample from the incubation tank using a beaker. The volume of the water in the beaker was noted. The eggs or larvae in the water sample were filtered and placed on a modified counting chamber and monitored under a microscope. Eggs were classified as either good or bad. Egg and larval counts as well as the hatching rate were determined using the following formulas:

$$\text{Good/Bad Eggs} = \frac{\text{number of eggs counted}}{\text{volume of water sample}} \times \text{volume of incubation tank}$$

$$\text{Normal/Abnormal Larvae} = \frac{\text{number of larvae counted}}{\text{volume of water sample}} \times \text{volume of incubation tank}$$

$$\begin{aligned} \text{Total Eggs} &= \text{Good eggs} + \text{bad eggs} \\ \text{Total Larvae} &= \text{Normal Larvae} + \text{Abnormal Larvae} \end{aligned}$$

$$\text{Hatching Rate} = \frac{\text{Total Larvae}}{\text{Total Good Eggs}} \times 100$$



The integrated milkfish hatchery and broodstock complex with two broodstock (A and B) tanks at Tigbauan Main Station

### Spawning success with higher water temperature

Figure 4 shows the monthly production of good eggs and the hatched normal larvae from January 2018 to February 2020. Spawning of milkfish in tanks occurs from March to October and ceases from November to February. This observation is synonymous with the previous observation of milkfish broodstock spawning naturally during increased water temperature. With the installation of water heaters in the tanks, spawning occurred from December 2020 to February 2021.

The result of the experiment is encouraging; however, it needs a longer duration and observation such as for a period of four years. The more extended experiment aims to establish the effect of water temperature on milkfish spawning efficiency, fecundity, fertilisation rate and larval abnormality rates. Water temperature manipulation in tanks of milkfish broodstock allows the fish to spawn during cold months or off-season. Along with the expansion of hatcheries and improvement of milkfish broodstock, this technology with further increase milkfish production in the Philippines and the dependence of milkfish fry imports.



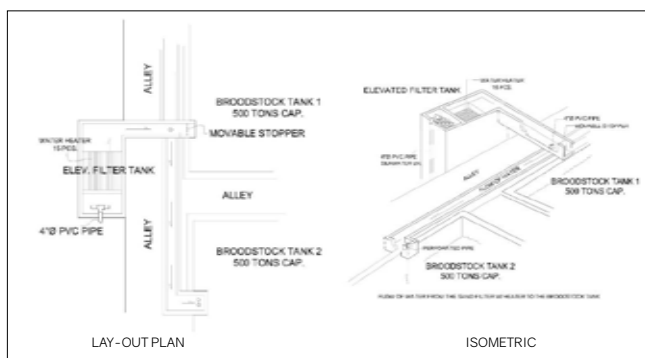
Left: sand filter tank and water supply canal; right: water outlet canal going to the broodstock tank



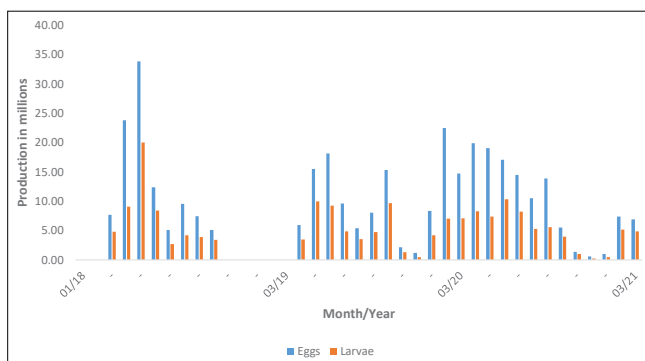
Water heaters installed near the sand filter tank



Milkfish fry



**Figure 3.** Schematic diagram of the filter tank, water heater setup and water canal and (right) the location of 15 water heaters.



**Figure 4.** Monthly production of milkfish eggs and larvae from January 2018 to March 2021.

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# The world of Artemia cysts as live feeds in marine shrimp hatcheries

Insights on current trends in *Artemia nauplii* production, usage and technologies



Artemia cysts and freshly hatched out nauplii. Picture provided by Dr Nageswara Rao PV, Managing / Director, Bluelife Aquaculture (P) Ltd.

The first FAO Technical Aquaculture Conference in Kyoto in 1976 observed that *Artemia* was a major bottleneck in successful aquaculture. Among the solutions to improve the critical situation included the exploitation of natural resources as well as improved techniques for cyst harvesting, processing, storage and hatching. The *Artemia* Reference Center (ARC), Ghent University, Belgium was setup in 1978, and since then, ARC has been conducting research and development on the biology and hatching technology of *Artemia*. FAO's 1996 manual for the culture and use of *Artemia* in aquaculture featured good aquaculture practices for *Artemia* production. However, over time, the practices used by hatcheries in Asia, Europe and Latin America have diverged from these recommendations.

Forty-five years on in September 2021, a webinar, attended by 359 participants from 53 countries and hosted by the Network of Aquaculture Centres in Asia-Pacific (NACA) documented current practices in fish and crustacean hatcheries on the use of *Artemia* cysts for the preparation of live feeds. During this webinar, there were short presentations on usage of *Artemia* cysts and how cyst decapsulation, hatching, umbrella/nauplii separation, harvesting, disinfection, storage, heat-killing/freezing, enrichment, etc. are performed in small- and large-scale marine shrimp hatcheries in Asia, Ecuador and Brazil and in fish hatcheries in Europe. In this article, the focus is on *Artemia* use in marine shrimp hatcheries.

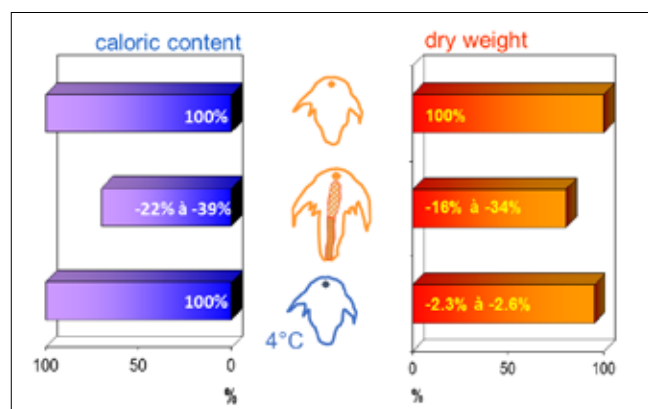
In his short introduction, Patrick Sorgeloos, Ghent University touched on some crucial parameters to ensure optimal hatching and preparation of *Artemia* for use in fish/crustacean hatcheries.

The consumption of *Artemia* has increased tremendously, from a tonne in 1970 to more than 3,000 tonnes from 2010 onwards. "Today, we see the consumption stagnating at around 3,500 tonnes of *Artemia* (valued at USD200 million). In the early years, hatcheries used around 25kg of *Artemia* cysts to produce 1 million shrimp post larvae but today it can be done using 2 to 3kg of *Artemia* cysts." He added that the current tendency is to increase again to levels up to 8 kg of *Artemia* cysts as new shrimp breeds apparently have higher needs for live food.

## Understanding the biology

Sorgeloos stressed its importance since some of this knowledge is not considered today in commercial operations. *Artemia* cysts are dry embryos commonly referred to as eggs, with 0.2mm diameter. They have less than 10% water content but are very hygroscopic. The cysts have zero metabolism but contain viable embryos: upon hydration embryonic development resumes. He also described how the outer cuticular membrane acts as a molecular sieve. Molecules of oxygen, water and carbon dioxide can go in and out but any molecule bigger than carbon dioxide cannot get through this molecular sieve.

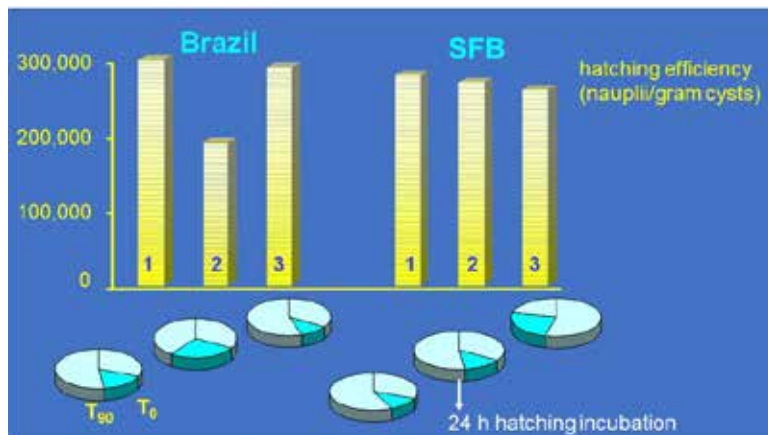
"This is important to know when we talk about removal of the chorion layer in producing the decapsulated cysts. Once fully hydrated, a light trigger is critical to start carbohydrate metabolism and the conversion of trehalose to glycogen and glycerol. Glycerol is hygroscopic and as more glycerol is produced more water will be absorbed and when the cysts break, the glycerol released in the hatching medium is a very good substrate for *Vibrio*." He added that at the instar II stage, the *Artemia* has an open mouth which means it is ingesting *Vibrio*. "We can limit contamination with *Vibrio* by feeding instar I, which is clean and when the nauplii have not started the ingestion process. The cold storage of *Artemia* nauplii instar I stored over 24 hours, at high density (5,000 ind/mL) guarantees the feeding of animals with the most nutritious source of *Artemia*."



**Figure 1.** Energy content of instar 1, II and cold stored instar 1 *Artemia* (Source: Patrick Sorgeloos, Brief introduction on the *Artemia* cyst hatching process and its use in hatchery feeding).

## Hatching synchrony

Hatching synchrony is the speed of hatching. Sorgeloos explained, “Synchrony of hatching can be very different from one batch and strain to another. A product can have very similar hatching efficiency in terms of number of nauplii produced. But over 24 hours incubation, you see some have finished hatching but some have yet to start. Maximising synchrony requires good light conditions and pH.”



**Figure 2.** Hatching efficiency and hatching rate of different batches of Brazil (Macau) and SFB Artemia cysts. (Source: Patrick Sorgeloos, Brief introduction on the Artemia cyst hatching process and its use in hatchery feeding).

## The global leader in Artemia cyst market

“In terms of usage, China is the global leader; it is the largest consumer as well as producer of Artemia cysts, using around 1,700 tonnes of dry Artemia products, which is about 50% of the global supply,” said Liying Sui, Director, Asian Regional Artemia Reference Centre, Tianjin University of Science and Technology. These are for larviculture of marine shrimp, mainly *Penaeus vannamei* (1,250 tonnes), freshwater prawn *Macrobrachium* sp (240 tonnes), Chinese mitten crab and marine fish, mainly grouper and sole (150 tonnes). A recent demand is by snails and large-mouth bass hatcheries.

The total nauplii production was reported in the Chinese Fishery 2020 Yearbook at 1,507 billion in 2019. No data for post larvae production was given. Liying said that as feeding protocols differs from hatcheries, no Artemia cysts data on consumption/million post larvae is available.



In China, **Liying Sui** said that demand for Artemia cysts has changed from seasonal to a year-round requirement.

“Demand for Artemia cysts has changed from seasonal to year-round requirement. There are also shifts in regional demand, from South China (e.g. Wenchang in Hainan Province, Zhanjiang in Guangdong Province and Xiamen in Fujian Province) to other regions in the south and north (e.g. Rizhao in Shandong Province, Tangshan in Hebei Province, Tianjin, etc.). Hatching facilities as well as techniques have also significantly changed.”

Since different Artemia cysts have their own characteristics in terms of biometrics, nutritional value

and hatching performance, Liying added that hatcheries have their own preferences on the origins of Artemia cysts depending on the aquaculture species. “Marine fish hatcheries need better separation of the nauplii from the shells and unhatched cysts, and in this aspect Artemia cysts from Tibetan salt lakes and Ebiet salt lakes (Russia) are preferred. *Macrobrachium* larvae require faster swimming nauplii and hatcheries favour Artemia cysts from Bohai Bay (BHB).

“Then we have preferences based on hatching performance; cysts with higher hatching temperature tolerance are favoured in summer in south China (e.g. Hainan Province) and cysts that hatch at lower salinity are preferred in regions with availability of low salinity seawater (10 ppt). Nutrition-wise, eicosapentaenoic acid (EPA) content is being emphasized by marine fish hatcheries since they do not wish to do any enrichment.”

A new business involves the production of fresh or frozen Artemia nauplii by specialized companies located near hatcheries. It started in 2005 in south China and today such companies are all over China. The annual production is 500–1,000 tonnes of nauplii biomass using 150 tonnes of dry cysts. The maximum production is >1,000 kg to 2,000 kg per company. This business accounts for 50–80% of the nauplii demand in China.

“The advantage is that we can use all kinds of Artemia cysts - low and high quality dry/wet cysts. Hatching is by professional teams which give better efficiency. Serving small and medium hatcheries, these reduce labour costs for on-site live Artemia nauplii production. The disadvantage is that usually instar III and IV are produced to get higher hatching output, with a reduction in the energy value of nauplii and increased risks of pathogen contamination.”

## Local production and imports of Artemia cysts

Data from the Artemia Association of China (AAC), indicated that, China harvests 1,200–1,500 tonnes of raw Artemia cysts (Figure 3). There was an extraordinarily high production of 3,500 tonnes in 2016, with Aibi Lake accounting for >50% of the production. China produces annually 800–1,200 tonnes of dry Artemia cysts. “China remains a large importer of raw Artemia cysts (2,000–3,000 tonnes) mainly from Russia (800 tonnes), Uzbekistan (500 tonnes) and Kazakhstan (350 tonnes), but also exports 400–600 tonnes of the final products to Vietnam, Malaysia and Thailand. Raw cysts imports fluctuated from 2,700 tonnes in 2015, 3,260 tonnes in 2016 to only 1,650 tonnes in 2020.

## Alternative Artemia products in China

Dry decapsulated Artemia cysts use low hatching quality cysts for the ornamental fish market which has an annual demand of about 20 tonnes. Normal hatching quality Artemia cysts are processed by specialized companies as decapsulated cysts and sold as wet products to hatcheries which will continue the hatching process. Annually 100,000 tonnes of Artemia biomass are harvested from coastal saltworks (Bohai Bay) and inland salt lakes (Yuncheng in Shanxi). These are also processed as frozen biomass cakes (55%) - small cubes as feed for ornamental fish and 1–2kg cakes for shrimp nursery and broodstock maturation and 5kg cakes as feed ingredient.

## Consistency in hatching rate in India

Nageswara Rao P V, General Secretary at the All India Shrimp Hatchery Association or AISHA, said that there are 401 SPF *P. vannamei* and 2 SPF *P. monodon* hatcheries. The 325-345 tonnes of Artemia cysts imported mainly from Great Salt Lake (GSL) are used to feed zoea III onwards stages (*P. vannamei*) and for late mysis stage (*P. monodon*). "There are some preferences such as hatching at >80% of richly pigmented harvested Artemia biomass, smaller size nauplii and low *Vibrio* loads. GSL is preferred because of the consistency in hatching rate. Decapsulation and disinfection of cysts are carried out to reduce contamination and speed up the hatching process. "In hatching, probiotics are used at 5-20ppm and ozone infusion into the hatching liquid reduces bacterial load and improves hatching percentages," said Rao. With translucent bottom tanks, light is used to attract nauplii to the tank bottom. "Hatcheries also prefer inactivated instar I to feed zoea/mysis stages which means that nauplii are frozen or chilled for 6-8 hours or inactivated in 100°C boiled water or stored at -20°C."



In India, **Nageswara Rao P V**, said, "There are some preferences such as hatching at >80% of richly pigmented harvested Artemia biomass, smaller size nauplii and low *Vibrio* loads."

Some problems encountered by hatcheries are high temperature fluctuations between day and night especially in winter; lighting fluctuations when hatcheries shift from daylight to artificial lighting; pH fluctuations of seawater and hatching medium; biosecurity; and lack of skilled labour. "Despite all the precautions and steps, many hatcheries reported high contaminations with *Vibrio*," added Rao.

## Modifications for efficiency

Aside from imports from USA, Russia and China, Vietnam has a locally produced *Artemia franciscana* Vinhchau strain which contributes a small proportion of the total demand for Artemia cysts. Nguyen Van Hoa, Cantho University said the hatchery owners will decide on which brand to use for cost efficiency and benefits. There is also a large-scale operation to produce ready to use fresh instar I, instar II and umbrella stage on demand. Kept at 4-8°C, these survive up to 48 hours.

Trinh Trung Phi, Technical Director explained operations and recent modification to improve efficiency at Viet-UC's shrimp hatcheries. Viet UC started hatchery operations in 2001. Today, it has nine shrimp hatchery units all over Vietnam, supplying 15-20 billion post larvae annually and has a 20% market share. It uses 60-80 tonnes of Artemia cysts per year and depending on the size of hatcheries, hatches 30-100kg of Artemia cysts per day, with 100kg/day at its Bac Lieu hatchery.



In Vietnam, **Trinh Trung Phi** described how Viet-UC has made modifications to improve efficiency and uses large 2.5 tonnes tanks for hatching.

"We have been applying Inve's SEP-Art technology since 2013 but now we have switched to the new CysTM 2.0 system also by Inve. We have also upgraded our production rooms. For hatching, we improved lighting and temperature control systems. We have less tanks - from 160 tanks of 300L to only 20 tanks of 2.5 tonnes. Each 2,200L can hold 4.4 to 6.6kg cysts. This allows us to reduce manpower. In the Bac Lieu hatchery, incubation is done 3 times a day and harvesting 23 hours later. The protocol is to ensure more than 80% of instar I and less than 20% of instar II."

## Umbrella stage

A unique innovation in Vietnam is the production of the umbrella stage Artemia. Hoa explained the process, "After 12-14 hours of incubation, aeration is stopped, and a stirring stick is used to separate the embryos from the shells. The percentage of umbrella stage Artemia can be 80% or higher." He added that in mud crab hatcheries, producing *Brachionus* sp rotifers successfully is laborious and replacing rotifers in feeding zoea1 with umbrella stage Artemia has been successful. "Whether umbrella stage Artemia can replace rotifers will depend on the strain. The Vinhchau strain has small dimensions relative to other strains and could possibly replace 100% of rotifers."



In Vietnam, **Nguyen Van Hoa** explained the process to harvest umbrella stage nauplii "Whether umbrella stage Artemia can replace rotifers will depend on the strain. The Vinhchau strain has small dimensions relative to other strains and could possibly replace 100% of rotifers."

## Traditional versus modern

"According to the Fish Import and Export Control Group, in 2020, Thailand imported close to 482 tonnes of Artemia cysts in 2020, down from more than 634 tonnes in 2019," said Montakan Tamtin, Director, Samut Sakhon Coastal Aquaculture Research and Development Centre, Department of Fisheries. The value went down to USD12 million in 2020. Imports are mainly for marine shrimp hatcheries. Artemia cysts are rarely used in seabass fry production to reduce production costs.

As high as 90% Artemia imports were from Russia and Asia (Uzbekistan, Kazakhstan, China) and 10% from USA. Canned products also include dried shell-free Artemia cysts. Chilled Artemia instar I & II in trays are convenient products marketed by I&V Bio since 2014.



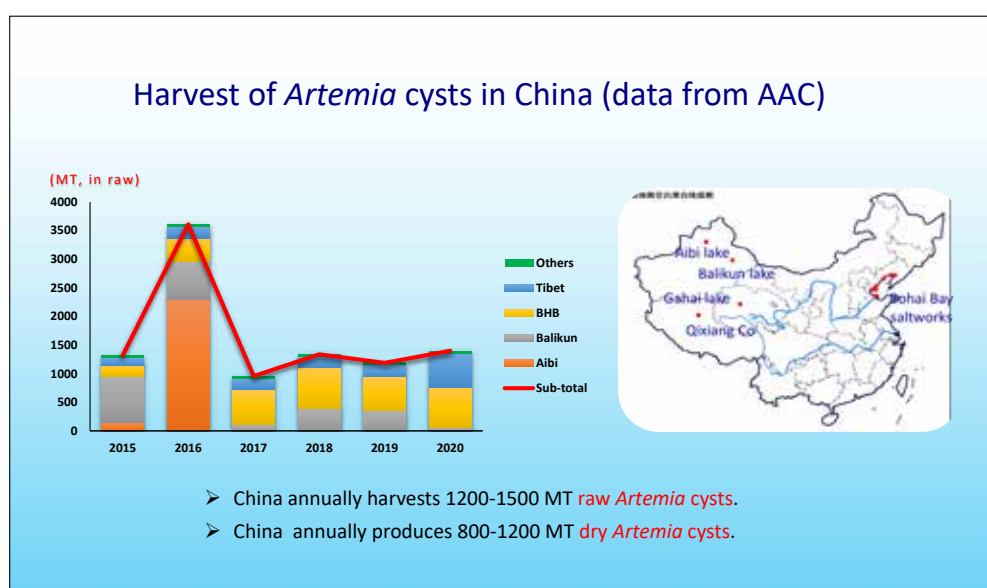
In Thailand, with regards to enrichment, **Montakan Tamtin**, said, "Today, with vannamei shrimp sold at PL10, enrichment is not really necessary. Some large farms do enrichment of 2-3 hours with vitamins and lipids."

"Most hatcheries use traditional hatching and harvesting methods. We have modern harvest tools such as SEP-Art Artemia using magnetic tools to attract and separate shells and get pure instar I. Feeding practices differ among hatcheries. Some hatcheries will rinse instar I with hot water before feeding to zoea3 -mysis 1 but others feed

Country	No of hatcheries	Consumption of Artemia cysts (tonnes) in 2020	Annual nauplii production (billion)	Annual post larvae production (billion)	Kg Artemia per million post larvae production
China*	-	1250 tonnes	1507	-	-
Ecuador	386	194.2 (2020)	159.5	79.7	2.4
India	403 (2 are for SPF monodon shrimp)	325-345 (annually)	billion	90	3.8
Vietnam	2300	400-500	270-280	140	3.0
Thailand	468 (2019, include nurseries)	482	66.6	33.0 (95% <i>P. vannamei</i> )	14.6
Bangladesh	59 (3 are for SPF <i>P. monodon</i> )	50 (include local production)		10-14	3.6
Brazil	20	20		25	0.8

**Table 1.** Consumption of Artemia cysts for shrimp nauplii and post larvae production in selected countries (\*China-Total of 1,507 billion nauplii were produced in 2019 according to the Chinese Fishery 2020 Yearbook. No data for post larvae production is available.)

**Figure 3.** Local production of Artemia cysts in China. Data from China Artemia Association (Source: Sui Liying, Zhang Bo and Gao Song. Use of Artemia cysts in hatchery in China).



mysis without rinsing. Some farms feed instar I, rinsed with hot water to feed zoea2-post larvae (PL6) prior to selling to farms. Some feed instar II rinsed in freshwater directly to mysis 3.

With regards to enrichment, Montakan said that in the past, with farming of the monodon shrimp and hatcheries selling PL15-16, enrichment over 24 hours with lipids and vitamins has a significant effect on larval quality. "Today, with vannamei shrimp sold at PL10, enrichment is not really necessary. Some large farms do enrichment of 2-3 hours with vitamins and lipids."

Large scale hatcheries use 90-100% chilled Artemia (instar I and instar II) and medium scale hatcheries used 40% chilled Artemia and 60% traditional dried Artemia cysts. Most of the hatcheries in the eastern provinces use 100% dried Artemia cysts from China. Small hatcheries use either 100% dried Artemia cysts or 90% raw Artemia cysts and 10% chilled Artemia or 80% dried, Artemia cysts and 20% chilled Artemia.

### Artemia for the monodon shrimp

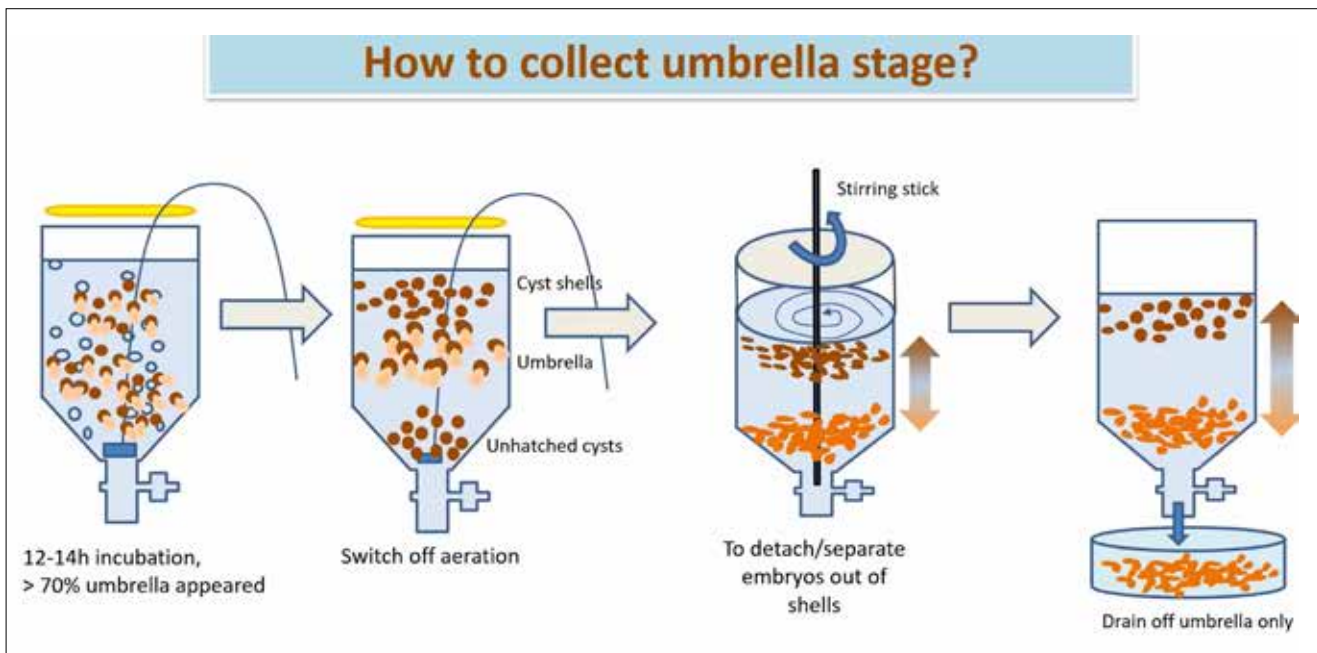
In Bangladesh, the yearly amount required is 50 tonnes of Artemia cysts for monodon shrimp and the freshwater prawn (*Macrobrachium* sp) hatcheries. WorldFish's

Muhammad Meezanur Rahman, who also leads the European Union project (Artemia4Bangladesh) said that in 2021, there were 59 hatcheries for monodon shrimp and 6 for freshwater prawn. "For this EU project, the *Artemia franciscana* seed stock came from Vietnam. Since 2020, we have supplied hatcheries with live Artemia biomass and the rest are frozen. Artemia nauplii are disinfected with chloramine -T, peroxide, formalin, antibiotics, probiotics and vitamin C prior to feeding post larvae, although these might not suffice to reduce the *Vibrio* loads."

While Rao said that temperature fluctuations between day and night especially in winter is an issue in India, Rahman said that high temperature fluctuations in summer can be problematic in Bangladesh. His other concerns are lack of observation on nauplii stages (instar I and II) harvesting, and poor Artemia nauplii preservation techniques.

### Artemia efficiency in Ecuador and Brazil

Ecuador imported 194.3 tonnes of Artemia cysts in 2020 for its 386 marine shrimp hatcheries. Up to May 2021, the volume imported was 71.89 tonnes. Data from the Ecuadorian Undersecretary of Aquaculture showed that nauplii production was 159.5 billion and post larvae production was 79.7 billion in 2020. Artemia cysts imports come from Russia (60%) and GSL (40%). Stanislaus



**Figure 4.** Collection of the umbrella stage was described by Nguyen Van Hoa, Cantho University in his presentation on the use of Artemia cysts in crustacean hatcheries in the Mekong Delta, Vietnam.

Sonnenholzner (Centro Nacional de Acuicultura e Investigaciones Marinas -CENAIM) said that 98% of hatcheries use decapsulated cysts and less than 2% use direct incubation. “In the decapsulation step, residual chlorine is not neutralised and effluents are washed directly into drainage.”

In the hatching step, cyst density in hatching tanks is 1g/L whereas the recommendation is 2g/L. Incubation is 24–36 hours. In the separation step, hydrogen peroxide will allow the membranes to float while brine solution will allow the membranes and debris to be drained out in conical tanks. “Freshly harvested nauplii are seldom offered to shrimp larvae. The usual practice is to heat kill the nauplii by dipping in hot water for 5–10 minutes and chilled/frozen for later use.”

Brazil has only 20 large marine shrimp hatcheries producing a total of 25 billion post larvae. The consumption is 20 tonnes of Artemia cysts per year of which 4 tonnes are locally produced in salt ponds. Practices in two hatcheries were described by Christine Macedo. Aquatec produces 2 billion post larvae year and Tecmares produces 3 billion post larvae/year. Aquatec uses SEP-Art Technology while Tecmares uses CystTM 2.0 with simultaneous washing and magnetic separation of nauplii.

Marcos Camara (Federal University of Rio Grande do Norte) and Macedo said most steps from disinfection to harvesting are in accordance with the standard operating procedures from manuals. Some challenges from hatcheries in northeast Brazil include standardisation of cyst decapsulation, nauplii cold storage practices and poor attention to the development of instar I and instar II to harvest the correct stage. According to Camara, there is also the use of juvenile and adult Artemia harvested in local salt ponds which are then frozen, freeze dried or processed into flake diets to feed shrimp larvae and post larvae.

## Conclusion

A webinar report (NACA, 2021) noted that many of the techniques and protocols, widely applied today, do not follow the good aquaculture practices (GAPs) in Artemia production as recommended in the 1996 FAO manual. An update of GAPs for Artemia cyst use in hatcheries was strongly recommended. Applying more standardised protocols will not only result in using a better and more biosecure food but hatcheries will be able to save on their Artemia cyst purchases.

New techniques and products have been developed and can result in more controlled and optimised use of Artemia cysts in hatchery practices. The use of the umbrella stage as was successfully applied in crab hatcheries should be considered for a wider application in aquaculture, as a new source of live food in earlier larval stages be it in shrimp or in fish. A wider use of Artemia enrichment technique was proposed. This method not only enhances the nutritional value of the nauplii but can also be used to do nutritional programming and as a vector to deliver for example pre- or probiotics to the fish/crustacean larvae.

In view of the large variety of species and strains of Artemia that are now available in the market, it might be time to better study their specific characteristics as well as to identify their most suitable application for specific species of fish and crustaceans. This could be related to their nutritional composition, synchrony in hatching, enrichment characteristics, etc.

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# Shifting to a sustainable new normal in shrimp farming in the Philippines

An environment-conscious growth is vital for the future as industry looks more toward export markets

Stakeholders in the Philippines shrimp farming industry are certain that it is a promising industry. Annual growth in the last 9 years was 16%. Growth is reflected by the number of hatcheries. There are 93 accredited hatcheries and larval growing facilities, 1,812 accredited and registered grow-out farms, and 37 processors and traders.

The highest growth was in 2019 at almost 12.7% with a production of 64,577 tonnes, according to official data from the Philippines Statistics Authority (PSA). In 2020, PSA reported a drop of 2.9% to 62,705 tonnes while the Bureau of Fisheries Aquatic Resources (BFAR) revised production to only 60,000 tonnes. This is much higher than other estimates. With a lower pandemic-related demand, Robins McIntosh (AAP, 2021) estimated only 57,000 tonnes. Ganancial (2021) gave a figure of less than 48,000 tonnes based on lower imports of broodstock. The industry was valued from PHP14.3-18.3 billion (USD 279.3-357.15 million) in 2020.

Projections point to possibilities of higher production volumes. According to Asis G. Perez, Consultant Feedmix Specialist II, 13.5 billion post larvae from 6,725 female broodstock can produce 269,000 tonnes of shrimp. "Even with 50-66% of this production, it will be roughly 90,000-135,000 tonnes." Maria Abegail A. Albaladejo, Chief of the Fisheries Planning and Economics Division, BFAR gave another view. She said if maximum productivity can be achieved at current registered farms, production can increase to 137,000 tonnes.

In its roadmap, BFAR has made projections for a steady and sustainable production. In the short term (2021-2025), the projected annual increase is 5,000 tonnes of *Penaeus vannamei* and 1,000 tonnes of *Penaeus monodon*. In the medium term (2026-2030), BFAR is working towards an annual production increase of 10,000 tonnes of *vannamei* shrimp and 2,000 tonnes of *monodon* shrimp and raising this to 20,000 tonnes and 5,000 tonnes, respectively, in the long term (2031-2040).

## Environment-conscious growth

This aspiration was echoed throughout the three-day program. "A sustainable and environment-conscious growth of the shrimp industry is vital to continuously contribute to national food security and economic growth. When it comes to economic growth, we are especially focused on livelihood opportunities that the shrimp industry creates even in the remote areas of the country," said Chairperson of the 13th Philippines Shrimp Congress, Norberto O. Chingcuanco to the Philippines News Agency. Secretary William D. Dar, Department of Agriculture added that over and beyond the technical

and market issues, the industry also faces issues like climate change and rising sea levels. "It needs to be resilient in handling the risks. There is a commitment to reduce greenhouse gas (GHG) by 75% in the Paris agreement."

The biennial 13th Philippines Shrimp Congress went virtual on November 9-11, 2021. Organised by BFAR and the Philippines Shrimp Industry Corp (PhilShrimp) the program revolved around the theme of "Philippine Shrimp Farming: Its Paradigm Shift to Sustainable New Normal." PhilShrimp's President, Roberto Gatuslao said that the timing was good as the industry is trying to manage uncertainties amidst the pandemic and global health crisis.

## Environment and climate changes

Professor Lemnuel V. Aragones, Institute of Environmental Science and Meteorology (IESM), University Philippines Diliman gave his views on environmental considerations for aquaculture. He believes that the industry should adapt or harmonise its operations according to environmental conditions and climate changes. "The aquaculture sector has not fully made use of the climatic data available, particularly in anticipation of rising temperatures, changes in precipitation etc. If the geomorphology of the islands (nature of land masses or coastal areas) is taken into consideration when aquaculture companies plan for development, the industry will be much more efficient and sustainable in the long run."

The country has four climate types where the pivotal roles are played by rainfall and monsoons. "It is impossible to ignore climate change in the Philippines where annually, there are almost 20 typhoons," said Chris Mitchum D. Ganancial, Marketing and Technical Manager at Hoc Po Feeds Corp. These typhoons move



Greenhouse super intensive shrimp farming in the Philippines. Picture by Dr Prakarn Chiarahkhongman, Charoen Pokphand Group Global (CPG).

in a northwesterly direction and sparing Mindanao, the southernmost island. “However, since 2012, a series of typhoons hit this island, and coincided with a series of white spot syndrome virus (WSSV) outbreaks in areas where it is not common.” Working with the Department of Science and Technology (DOST), to monitor weather changes, Ganancial has linked WSSV and fish kills to low pressure trends and thermal stratification. In the future, he plans to update the information and develop an app for farmers to monitor weather conditions.

### Competitiveness and culture efficiency

“Presently, the Philippines is a small player compared to regional producers, and an increase in volumes means more intensification in production. The Philippines should look at the shrimp models in India, Vietnam, Thailand and Indonesia and their success, and learn from them. It is always about being competitive,” said keynote speaker, Senator Cynthia Villar who chairs the Senate Committee on Agriculture and Food, and Senate Committee on Environment and Natural Resources. She added that the industry will forge ahead with public, private partnerships.

Industry leaders have lamented often on the high costs of production (COP) due to high feed costs, energy and transport, among others, in comparison with regional producers. In 2021, COP in the Philippines rose by USD 0.15 to USD 3.67-4.00/kg for harvest of size 70/kg at the stocking density of 100 PL/m<sup>2</sup>, because of higher feed costs. In comparison, it was only USD3.60 to produce larger shrimp (size 60/kg) in Malaysia and USD2.69-3.00/kg for size 60/kg in Thailand (Merican, 2021). Nevertheless, Ganancial said that farms have managed with good margins selling into local markets. He gave margins of PHP70-100/kg (USD1.36-1.94) at COP of PHP150-180/kg (USD2.92-3.50/kg). Chiarahkhongman (2021) gave production costs of PHP180/kg (USD 3.50/kg) in Luzon and PHP170/kg (USD 3.30/kg) in Visayas and Mindanao while selling prices (base 10g) were PHP 220/kg (USD 4.28/kg in Luzon and PHP180/kg (USD 3.50/kg) in Visayas.

The session on culture focused on which direction the industry should adopt – extensive or intensification. “While it is good to be focused and produce efficiently using smaller areas, for the Philippines, a concern is the use of less manpower,” said Perez. “We will need to find a win-win approach, perhaps super intensive production in some areas which target export markets and extensive production to supply the local markets,”

Dr Prakan Chiarahkhongman, Charoen Pokphand Group Global (CPG) presented on some recent cost-effective trends for farmers to adopt based on their situations and locations. While the tendency is always to control daily costs by searching for cheaper inputs from feed, post larvae

and even cheaper health products, Chiarahkhongman said that higher production costs come from crop failures, damaged ponds, high FCR, low average growth rate and longer culture duration. “Major problems and crop failures are due to stocking at high density without carrying capacity analysis, poor post larvae quality, costly feed as well as inappropriate management practices.”

A comparison of culture technology, risk factors and return on investments favoured new systems such as circular tank, small ponds and greenhouse tanks (Figure 1). He pointed out the differences in carrying capacity between different systems (circular tanks, small ponds etc), fast growth genetics and damaged ponds versus successful ponds. In the latter, the difference in production costs can be 136%.

### The pandemic and local consumption

The shrimp market pattern in the Philippines is quite clear; production in the first half of the year is for export and in the second half for local markets mainly in Manila and Cebu. Some 90% of the production is for local consumption. The target market for vannamei shrimp is food service. However, in Cebu, local demand from food service dropped 10-15% drop due to the pandemic. In Manila and Cebu, frequent lockdowns affected demand.

Gina Regalado, Vice-President, Intaq, explained, “With this pandemic, we see a lot of people out of work and as a result they looked for cheaper seafood. This upset our market trends. Already early in the pandemic, suppliers stopped imports and with high inventory and eager to offload stocks, they offered imported shrimp at much lower prices than locally produced shrimp.”



Gina Regalado, Vice-President, Intaq, described how the market was shaken by the pandemic.

She added that the opportunity for an increase in local consumption may come soon with the reopening of restaurants at 70%. “Demand will be for PD, PDTO, and nobashi shrimp using small 10g shrimp and packed in small 1kg packets. Since August 2021, we cannot ship out shrimp due to the lack of containers and neither can we import shrimp to boost our inventory. Retail to supermarkets has made up for the loss in food service. Working from home, many consumers purchase luxury seafood such as shrimp in small packs of 250g. Pre pandemic PD shrimp was sold for PHP400/kg (USD7.78/kg) and rose 30-40% during the pandemic. Demand is also for small shrimp and soft-shelled shrimp for value added products such as shumai.

Type	Development Cost (PHP/ha)	Risk factor	Management factor	Productivity (tonnes/ha)	Profitability (PHP/kg)	Return on investment (%)
Circular tank (BCT)	High	Low	High	High	High	High
Small pond (BSP)	High	Low	Medium	High	High	High
HDPE lined pond	Medium	Medium	Medium	Medium	Medium	Medium
Earthen ponds	Low	High	Low	Low	Low	Low
Greenhouse (future)	High	Low	High	High	High	High

**Figure 1.** A comparison on culture technology as presented by Dr Prakan Chiarahkhongman, on recent cost-effective trends in shrimp farming technology.

Type	TANK	SMALL POND	HDPE LINED	EARTHEN
Ave. Pond/Tank Size (ha)	0.08	0.28	0.54	0.58
Ave. Density (pcs/m <sup>2</sup> )	281	172	132	97
Ave. DOC (days)	98	91	98	111
Ave. Final ABW (g)	32.1	26.1	26.3	25.5
Ave. Mean ABW (g)	24.3	21.5	21.7	20.9
Ave. Daily growth (g)	0.32	0.29	0.27	0.23
<b>Ave Production (Ton/ha)</b>	<b>61.8</b>	<b>32.6</b>	<b>28.2</b>	<b>19.0</b>
Ave. FCR	1.30	1.36	1.39	1.42
Ave. Survival Rate (%)	93.5	87.3	84.1	76.7
Ave. Production cost	180	170	160	150

**Figure 2.** A comparison of culture technology and benefits as presented by Dr Prakan Chiarakhongman, on recent cost-effective trends in shrimp farming technology.

“In 2020 to 2021, we saw some ingenuity in marketing shrimp too. This is an opportunity for farmers to use technology to go direct to the consumers in large cities (Manila and Cebu). While fresh shrimp has been a norm, we see this preference for fresh shrimp changing to frozen PDTO, HOSO and nobashi for the local market.”

Regalado said that today, the outlook is looking good as Vietnam, Thailand, and China have announced that prices are increasing. “Can we look at an additional PHP20-30/kg in prices?”

### Challenges for the processor

Louie Antonio C. Libarios, the second generation in the family-based seafood processor and exporter De Oro Resources Inc, based in Cebu said, “In terms of raw material availability, June to October is the high season. Volumes are smaller in November and December, but prices are high with high demand as consumers prepare for Christmas and the new year season. There are no materials to process from January to mid-May”.

“For us, this seasonality in raw material means that for almost 5 months, there is almost no work for the workers. We lose 70% of our workers during the offseason. When the season starts again, 30% of them return and we retrain the new workers as well as the old ones. We take 2 months to do this. The cycle repeats with the offseason and new season.”

Logistics posed problems during the pandemic years. “We harvest farms in different islands and there are limited numbers of persons allowed on trucks and therefore, I cannot send the whole harvest team. My team of harvesters are very skilled, they know how to take care of the harvest well. These new measures have forced me to hire local and inexperienced labour. This year, there has been several occasions when we incurred losses because of poor handling. Changes of rules overnight with new directives

from the local government on Covid-19 protocols did not give us time to adjust since we had already scheduled harvesting. Such incidences create delays and deterioration of the products.

“During this pandemic, it is ironic that here in the Philippines, because of reduced imports of shrimp, suppliers then asked processors for local shrimp. It should be the other way round, imported shrimp should substitute local shrimp.”



Louie Antonio C. Libarios, De Oro Resources Inc said that during this pandemic, a major challenge was logistics; demurrage costs have increased since it takes longer to clear containers with labour shortages.

He added, “Shipping costs have doubled. Demurrage costs have increased since it takes longer to clear containers with labour shortages; it takes 2-3 weeks instead of a week previously. Buyers incur additional costs and this cuts into prices. Logistics cost has always been high in the Philippines. It costs the same to ship to Japan (5-7 days) as it is to ship to Manila (overnight or 2 days). Other challenges are the continuous increases in costs such as for packaging which have been increasing. He expects more increases in energy costs”.

### Exporting Philippines shrimp

According to the National Economic Development Authority, in November 2020, due to the pandemic, shrimp export value dropped to PHP20 billion (USD389 million) from a high of almost PHP70 billion (USD 1.36 billion) in 2017.



**Maria Abegail A. Albaladejo** said that BFAR has projected, in the short term (2021-2025), an annual increase of 5,000 tonnes of *Penaeus vannamei* and 1,000 tonnes of *Penaeus monodon*



**Chris Mitchum D. Ganancial** presented on “Linking WSSV outbreaks to abrupt changes in weather conditions and showed how to access information on air pressure at the DOST-Pagasa website.



A sustainable and environment-conscious growth of the shrimp industry is vital to continuously contribute to national food security and economic growth - **Norberto O. Chingcuanco.**

The peak volume for exports was in 2010 at 11,706 tonnes. The top export destinations are Japan, USA, Korea, Taiwan and France. Libarios said, "Even before the pandemic, we do not have a strong market presence for our shrimp. We started with the Japan market with black tiger shrimp. We have been exporting vannamei shrimp since 2012-2013 but our overseas buyers are still surprised that the Philippines has vannamei shrimp."

"There should be a strategy to be competitive, to get a slice of the global shrimp market," said Elizabeth Cristina Pahilan, Senior Investment Specialist, DTI-BOI, as she moderated a session on marketing. Market access remains a bottleneck. Local companies need to pay attention to the demands of buyers for certifications, which differ from one market to another.

"Some demand for testing by local accredited laboratories and others insist on testing from laboratories outside the Philippines. We need some harmonisation; Australia wants tests for viral pathogens but turnover by laboratories outside the Philippines is around 15 days aside from being costly. Thailand has got their systems correct and we need some guidance."

"Most of our trading partners have their own requirements and we need to adjust to their needs. So far, we have been working well with requirements from buyers from South Korea, Russia and Japan. They require that products are safe and farms are monitored by BFAR for diseases," said Dr Sonia S. Somga, National Fisheries Laboratory Division, BFAR.

Jyoti Bhasin, Managing Director, APEC Region at NSF International Co. Ltd who presented on certification in the shrimp industry, added, "Certification is an investment. In India, BRC, BAP are norms. The younger under 40 consumers look for food safety and organic products, they scan QR codes to understand traceability of products."

## Strong government support

Undersecretary Cheryl Marie Caballero, Agriculture Industrialization and Fisheries, Department of Agriculture and Food, announced some efforts to enhance the nation's shrimp aquaculture industry. Since vannamei shrimp is the dominant species comprising 91% of the production, efforts are ongoing to increase production of monodon shrimp such as the "Oplan Balik Sugpo" program between SEAFDEC and BFAR (see issue, November/December 2021). The top two monodon shrimp producing provinces are Pampanga and Lano del Norte. The top five vannamei shrimp producing provinces are Sarangani, Cebu, Zambales, Cagayan and Bohol.

An important government contribution is ensuring supply of post larvae. BFAR has begun setting up and funding a broodstock multiplication centre for vannamei shrimp, a monodon hatchery in Mercedes, Camarines Norte as well as additional shrimp hatcheries. In addition, there are massive education and information campaigns, shrimp disease surveillances and monitoring, technical training and online training on the fundamentals of shrimp aquaculture and business opportunities.

## More updates on trends in the region

With regards to learning from other regional players, several presentations provided updates. In shrimp larval nutrition, Dr Craig Browdy, Zeigler Bros, USA, discussed practices to increase efficiency and profitability and compared hatchery feed management in Asia and Latin America. Erik Ballaer, INVE Aquaculture showed the new developments in hatcheries in Thailand. Henry Cuong, ADM, introduced a biosecure nursery system in Vietnam. In grow-out ponds, Dr Olivier Decamp, Grobest, discussed the benefits of functional feeds and Simon Ong, GS Biotech, discussed some challenges in farming shrimp in Malaysia.



The panel on DOST programs and services to support industry was moderated by Professor Veronica Migo, Department of Engineering, Agro-Industrial Technology, UPLB.

# Marine Shrimp in Asia: Recovery in 2021

Higher production levels signify a recovery from low volumes in 2020. As food service reopens, a conundrum for farmers to increase supply amidst rising costs of production

By Zuridah Merican



Shrimp pond in Vietnam. Picture credit. Uni President Vietnam.

In this second year of the pandemic, there are several positives for the industry in Asia. The markets, both retail and food service, have seen net increases and are pushing up demand for shrimp. Living with lockdowns is the new normal. The downside is the supply chain which is determining ex-farm prices as processors adhere to Covid-19 SOPs in countries such as Vietnam which faces issues including labour, exports of shrimp amidst the disruptions with freight containers and inspections of the virus on packaging. In 2021, farmers face higher costs of production from higher feed costs, as feedmillers began to pass on rising feed ingredient costs to farmers. This article will look at production trends in leading producing countries, and some challenges and issues.

## Production in 2021

The annual GOAL survey gave a total production of both vannamei and monodon shrimp at 3.09 million tonnes in 2021 for countries in Southeast Asia, India and China. In Undercurrent News (December 2021), Robins McIntosh, Charoen Pokphand Foods (CPF) presented a total of 3.03 million tonnes. This report will discuss production data using estimates from the GOAL survey (see pages 53-54), those by industry and McIntosh. The top producers in Asia in 2021 were China, Vietnam, India, Indonesia and Thailand. The other smaller players are the Philippines (see pages 46-49), Malaysia and Bangladesh, which McIntosh said, produced 64,000, 52,000 and 40,000 tonnes, respectively. Vannamei shrimp farming was allowed in Sri Lanka in early 2020. The estimate on total production of both monodon and vannamei shrimp in 2021 is 16,000 tonnes and the forecast for 2022 is 25,000 tonnes (Shrimp Insights, 2021).

## China

While there are doubts with the reliability of FAO data for China, industry in the country maintains that production in 2021 would fall within the 1.2 million tonnes range to reflect recent developments in farming. This is despite recalculations presented at GOAL 2021. McIntosh estimated a production of 860,000 tonnes, up from 720,000 tonnes in 2020. At TARS 2021, Lee Ho, Zhanjiang Gangyang Aquatic Co Ltd had estimated a local consumption of 2.4 million tonnes in 2021. Lee also estimated a total import volume of 520,000 tonnes of vannamei shrimp for 2021 while Globefish (2021) reported that for the first time in three years, shrimp imports slowed down in China during January-June of 2021 with average monthly imports down to 48,000 tonnes. It noted that for the first time in many years, China reported increased shrimp exports during the first half of 2021.

A low inventory with container shortages and lengthy clearances and transportation into inland areas were reported. This encouraged more local production as well as good ex-farm prices of CNY40/kg (USD6.3/kg) for size 60. Demand is expected to remain strong after the Chinese New Year festival, but supply is low because of diseases and low survival rates. China's largest seafood industry association said that farmers are now producing more monodon shrimp due to better prices and domestic consumption (agri.hunghau.vn)

## India

In October 2021, industry in India estimated a slightly higher production for 2021 at only 5% from the 650,000 tonnes in 2020 while McIntosh estimated 700,000

tonnes. The final production estimate will depend on the performance of the second crop. "The winter crop as well as our monsoon season usually suffers from white spot syndrome virus (WSSV) outbreaks but this year, rains were heavier than last year and we had two cyclones. Some farms had outbreaks of WSSV, 30-40 days after stocking. For restocking, post larvae were not available from hatcheries around Chennai, which were affected by the cyclones with water salinity dropping drastically. Post larvae (PL) prices rose to 38-37 paise/PL (USD4.9-5.1/1000PL) from the usual 30-32 paise/PL (USD4.0-4.3/1000PL)," said Dr Ravikumar Bangarusamy, Growel Feeds.

In 2021, the estimate on monodon shrimp production was 60-70,000 tonnes. There are now 7-8 approved hatcheries to import broodstock. An attraction for the hatchery segment is the high selling prices of INR1/PL (USD13.41/1000PL). Its farming is popular among farmers running a single crop/year. Gujarat leads in its farming, followed by southern Andhra Pradesh and West Bengal. Ex-farm prices are good at INR540/kg (USD7.24/kg) for size 50. Production is expected to increase to 100,000 tonnes in 2022.

Almost 99,000 tonnes of HOSO shrimp were consumed in domestic markets in 2021, according to Venkat Kalagarla, Charoen Pokphand India at the MPEDA/SAP webinar "Taking Farmed Seafood to the Consumers". He expects an increase of up to 20% year on year and explained that markets in northern India prefer frozen shrimp and will pay higher prices while those in south India want chilled shrimp. E-commerce is booming; marketing, branding as well as ensuring shrimp are free from antibiotics are important considerations. He also stressed on the need to explain to consumers on carbon emissions, nutritional benefits and applying blockchain technology.

## Vietnam

The industry estimate is at 820,000 tonnes in 2021, comprising 520,000 tonnes of vannamei shrimp and 300,000 tonnes of monodon shrimp, of which 80% were from extensive ponds. This estimate contrasted with a lower 630,000 tonnes (UCN, 2021). The Directorate of Fisheries gave a production estimate of 931,000 tonnes, comprising 265,000 tonnes of monodon and 666,000 tonnes of vannamei shrimp (ThuySan, 2021). Industry leaders attributed high production to the innovations in farming and intensive culture systems for the vannamei shrimp, stocking 150-500 PL/m<sup>2</sup> and productivity of 100-200 tonnes/ha. This intensification has been ongoing, more so since 2020, noted Dr Loc Tran, ShrimpVet Laboratory at TARS 2021. However, the challenges are pollution with high nitrite levels. EMS/AHPND and WFS persist as well as muscle necrosis as reported in issue January/February 2021. To combat this, farmers resort to high water exchange at 30-50%, thus increasing energy costs. Loc said that farmers improve product value by using carotenoids to increase colouration for premium markets. A recent development is using light technology to increase metabolism and growth.

There are plans to increase production in 2022 but there are challenges such as quarantine requirements for exports and heat treatment requirements by Korea and Brazil. There are also the complicated Covid-19 SOPs affecting the supply chain from raw materials to labour. Production targets for 2022 total 950,000 tonnes,

comprising 275,000 tonnes of monodon and 675,000 tonnes of vannamei shrimp.

## Indonesia

Industry has estimated a total production of 445,000 tonnes in 2021, a significant increase of 27% from the 350,000 tonnes estimated for 2019 and much higher than 400,000 tonnes presented by McIntosh. "This volume was more in line with the feed usage and our higher than expected, shrimp export volume," said Haris Muhtadi, Chair Aquafeed Division, Indonesia Feedmills Association (GPMTT) and PT CJ Feed and Livestock Indonesia.

The government has a long-term plan to increase production by 250% to 2 million tonnes by 2024. Romi Novriadi, Ministry of Marine Affairs and Fisheries explained that the strategy involves various plans from developing some 11,000ha into new shrimp estates and integrated shrimp farming systems producing 40 tonnes/ha/year. Other plans include supporting intensive farming using 4.0 technology: transforming more than 40,000ha of semi-intensive farms into intensive farming models and converting traditional farms into extensive ponds following the Ecuadorian model. At a webinar "Shrimp Talks" to discuss the strategy, industry leaders said that the cost of production in Indonesia is much higher than India and Ecuador, thus adversely affecting competitiveness.

## Thailand

Industry's estimated production in 2021 at 263,377 tonnes was lower than the 280-282,000 tonnes mentioned by McIntosh and Somsak Paneetayasai, Thai Shrimp Association (Bangkok Post, 2021), respectively. This is a decline from the 2019 production of 317,839 tonnes. In 2022, Thailand expects to increase exports by 10% in volume from the 160,000 tonnes forecasted in 2021. The production target in 2022 is 300,000 tonnes. Paneetayasai wants the government to help boost domestic shrimp consumption to 1.5kg/capita or 99,000 tonnes per year in 2022, from 1.15kg/capita or 75,720 tonnes in 2021.

## Broodstock and hatchery

In 2021, with better management of broodstock supplies, India resumed post larvae production to the same level as in 2019. The pandemic raised the need for supplies of broodstock to meet real time demand. This weak link was underscored by Steve Arce, Kona Bay Shrimp – Hendrix Genetics Aquaculture Unit during TARS 2021. "The distance between the broodstock breeding centres and the hatchery has an impact on the condition of the broodstock. As was experienced in 2020, flight cancellations and delays resulted in increased mortality on arrival and stress to broodstock. Broodstock costs are high as well as freight charges." An additional push is the need to reduce carbon footprint of broodstock (Salazar, 2021). The solution is broodstock multiplication centres (BMCs) to supply local markets.

In October 2020, MPEDA restarted its two BMCs and distributed broodstock to hatcheries in June 2021 (Shrimp Insights, Oct 2021). PT Kona Bay Indonesia began exporting broodstock to Sabah, Malaysia in November 2021 (Banten news). Similarly, industry leaders in Indonesia highlighted a need for adequate post larvae supply with the strategy to increase production by 250%.

Country	Direct cost/kg (USD)	SD/m <sup>2</sup>	SR%	Harvest size (shrimp/kg)
Thailand	3.36	150	90	100
Thailand	3.92	150	75-80	30
Malaysia	4.35	180	80	46, CPF combine system, 70 days
Malaysia	3.60	70	70	60, earthen pond, 85 days
Malaysia	3 -3.75	80-100	70-80	50-35, earthen pond
Philippines	3.67-4.00	100	80	70
India	2.71	25	85	60
India	2.47	32	90	100
Vietnam	3.00	80-300	80	100
Vietnam	4.30	80-300	80	30
Indonesia	2.48-3.54	100-200	30-90	100
Indonesia	3.00	180-200	90	70

**Table 1.** Some examples of costs of production for vannamei shrimp with inputs from industry. (Source: Zuridah Merican, Effects of the Pandemic on the Global Shrimp Industry. Presented at 13th Philippine Shrimp Congress, Nov. 9-11, 2021).

### Rising cost of production

Farmers felt the burden of higher shrimp feed prices in May 2021 with increases at a range of 2.7 to 6.3% in India and 3.8 to 5.5% in Vietnam, depending on feed type. Thailand's Ministry of Commerce permitted feedmillers to implement an increase of 3% in November. At the same time, farmers have been seeing production costs rising because of low survival rates due to disease. In Java, Indonesia, the cost of production ranged from IDR35,000-50,000 (USD2.4-3.5/kg) for size 100 depending on how well the farmer manages to control diseases and survival rates can range from 30% to as high as 90%. Average stocking density is high in Indonesia at 100-200 PL/m<sup>2</sup>. The range for feed prices is large from IDR12,500-17,000/kg (USD 0.87-1.18/kg), depending on the protein content. In East Malaysia, when farmers push to harvest larger shrimp of 25g-28g, feed conversion ratio (FCR) rises above 1.4. Stocking at 80-100 PL/m<sup>2</sup> reduced costs to MYR18/kg (USD4.3/kg) whereas in high stocking conditions, cost of production rose to MYR20/kg (USD4.77/kg), said Ong Si Mon, GS Biotech.

In India, Manoj Sharma, Mayank Aquaculture, described the discrepancy in costs of production between regions. Overall, it is an extra INR40/kg (USD0.5/kg) in Gujarat as compared to Andhra Pradesh. Cost to produce size 60 shrimp was INR215/kg (USD2.9/kg) in October 2021 in Andhra Pradesh rising to INR260/kg (USD3.48/kg) for larger size 30 shrimp. Average stocking density was 40 PL/m<sup>2</sup>.

### Ex-farm prices

In the first quarter of 2021, ex-farm prices were high in China, according to Globefish (2021). In India, lower supply but high export demand at the end of the year raised ex-farm prices - INR390/kg (USD5.2/kg) for size 60 and INR495 (USD6.62/kg) for size 40, said Gulrez Alam, Secretary, Shrimp Feed Millers Association. Prices have been high since July/August 2021 due to low supply from farms and lower farming activity because of increased costs of production from high feed prices. China is India's large market for 10-17g shrimp.

Towards the end of 2021, VASEP noted that with rising demand, ex-farm prices for vannamei shrimp in the

Mekong Delta were high at VND120,000-140,000/kg (USD5.3-6.1/kg) for size 40-60 shrimp. It added that with such ex-farm prices, shrimp farming was still profitable despite higher prices for feed and chemical inputs. In mid-2021, despite low supplies, shrimp prices of all sizes in Thailand remained at the lowest level since 2018 (agrihungau.vn). Prices only went up to THB180/kg (USD 5.4/kg) for size 60 in December after a period of low prices from January to July at THB150/kg (USD4.5/kg).

### Outlook 2022

RaboResearch (January 2022) has published a good summary of the outlook for 2022. Shrimp will have a very strong year led by a rebound in the food service sector in both the US and EU. China, which is the other major market is expected to follow, albeit with a lag due to stricter controls in its 'zero-Covid policy'. Supply is also seeing a rebound as the CAGR in 2021 shows close to 9% compared to the past 20-year average of 5%. This will put shrimp production above pre-pandemic 2019 levels. Ecuador and India will lead the export supply to both the US and the EU. It is predicted that Ecuador will breach the one million tonnes mark in 2022.

Despite inflation and increasing seafood prices, consumers seem to accept farmed seafood. In the food service sector, this could be due to the higher income bracket of consumers who may not have been affected by the pandemic. Furthermore, beef and poultry prices have also increased globally such that the relative price of shrimp in comparison will allow it to gain market share (J. Anderson, Animal Protein Outlook 2022). Chinese New Year 2022 will see a larger share of food purchases going for frozen seafood. As a result, shares in Zhanjiang Guolian Aquatic Products have gained 20% on January 14 (Financial Times, January 2022).

Feed ingredient and energy costs will push feed prices upwards and the industry will look for novel proteins to fill this supply gap in a sustainable way. Many feed companies are already looking at the life cycle assessment (LCA) of various ingredients and opt for those with a minimal carbon footprint.

References are available on request

# GOAL 2021: Global farmed shrimp supply

In 2021, Ecuador's production saw a massive increase to an estimated 940,000 tonnes and optimism of recovery in production was realised by most leading producers

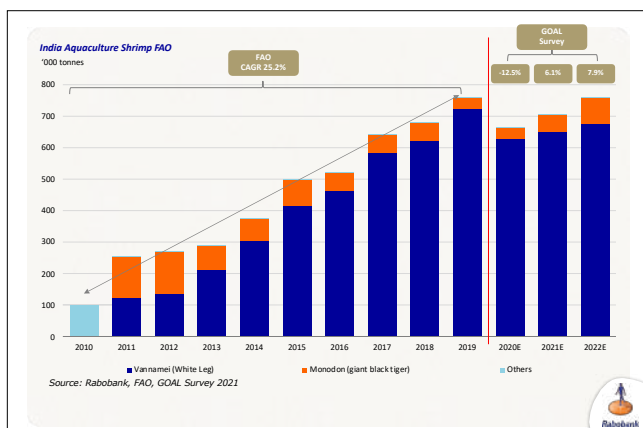
The 2021 global shrimp aquaculture production survey and forecast was the highlight of GOAL 2021. It was presented by Global Seafood Alliance (GSA) and Rabobank. In 2021, the Global Aquaculture Alliance was rebranded as GSA. GOAL 2021 comprised a series of sessions held over the year and ended with the final one on November 17, 2021, with this annual forecast on shrimp and finfish production. Gorjan Nikolik, Rabobank, presented the results of the annual survey. Some interesting takeaways from this year's report was the phenomenal production increase by Ecuador and the recalculation on production from three Asian countries; China, Indonesia and Vietnam.

## The Americas

**Ecuador** is the most important country in shrimp farming and has been on a phenomenal growth path even before the pandemic. "Covid only slowed down its growth," said Nikolik. "The latest figures by GSA sources indicated that Ecuador has reached 940,000 tonnes with USD4.6 billion in exports. The survey was conducted over the last 2 months, and this showed how the shrimp industry can pivot quickly given its very short cycle."

**Mexico** has been on a recovery period since 2013 and the pandemic did not help. "Previously, the survey showed that a recovery was expected in 2021 but with the latest production figure of 162,000 tonnes which was at the same level as 2019, this did not occur," noted Nikolik. "**Brazil** has been the sleeping giant in the Americas. New figures from GSA showed a spike in production to an estimated 100,000 tonnes in 2021 and a bullish 2022 with 120,000 tonnes."

Other producers such as Peru, Honduras, Nicaragua and Guatemala, all expanded production. The forecast for these producers is that by the end of 2021, production would be 10% higher.



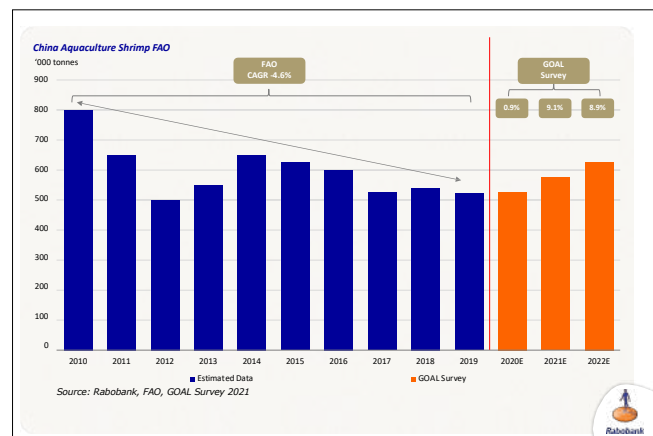
**Figure 1.** India shrimp production. GOAL survey data forecast a small recovery in 2021.

## Asian production

While Ecuador is the country to watch, in Asia, it is **India**. Until 2020, India recorded impressive growth. Year 2020 was a difficult year, and a 12.5% drop would be realistic, noted Nikolik (Figure 1). In 2021, cyclones and the pandemic impacted production. The forecast is that

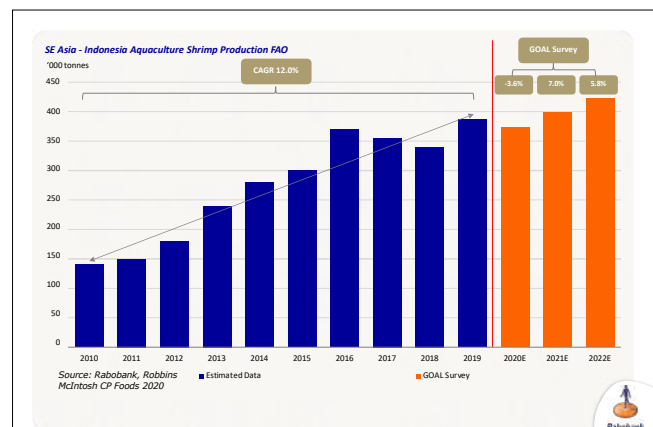
India may take 2 years, until 2023, to recover from the contraction in 2020 and get back to its peak production of 2019.

Issues with the official data on China persist. Using FAO's data, **China's** production was on an increasing upward trend almost reaching two million tonnes in 2019. However, industry participants of the survey said that official figures were too high. An alternative was to use data from industry sources, but it was difficult to get a consensus on the correct data to use. Taking the percentage change rather than nominal value from survey respondents, data closer to reality was presented. The production was just more than 500,000 tonnes in 2020 - increasing 9.1% in 2021 and 650,000 tonnes (+8.9%) in 2022 (Figure 2).



**Figure 2.** Chinese shrimp production based on industry data and suggested percentage change by survey respondents. Industry data showed a production of just more than 500,000 tonnes in 2020 but rising in 2021 and 2022.

In the case of **Vietnam**, the GOAL baseline survey of 2015 was used to make corrections. Nevertheless, Vietnam's industry is growing; 1% growth in production in 2020 and is poised to increase in 2021 by 13.6% and a marginal 0.9% in 2022. Production estimated for 2021 was around 750,000 tonnes of vannamee and monodon shrimp.

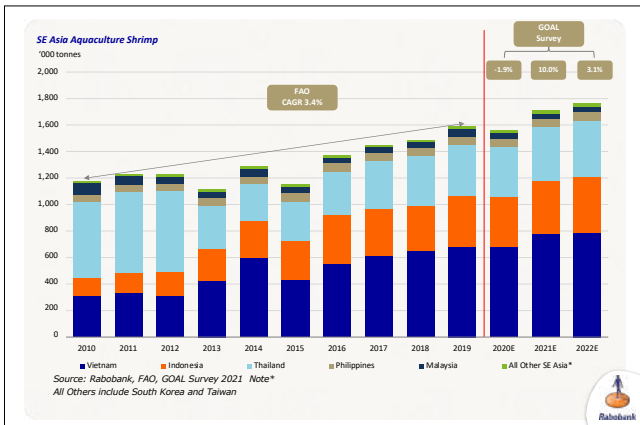


**Figure 3.** Indonesia shrimp production using industry data showed a production of 400,000 tonnes in 2021 and increasing by 5.8% in 2022.

The official production figures for **Indonesia** were also deemed as too high. The reality is lower production volumes. Official FAO figures indicated 900,000 tonnes production in 2019 whereas industry sources gave production estimates of less than 400,000 tonnes. The discrepancy was more than twice. Using the same methodology as for China, the survey reported a contraction in 2020 and growth by 7.0% in 2021 to 400,000 tonnes and 5.8% in 2022 (Figure 3)

**Thailand** is still a large producer although it is no longer a leader. Nikolik updated the latest information of a production estimate between 320,000–325,000 tonnes in 2021 which implied that the expected growth in 2021 did not materialise. More growth is expected in 2022. The survey showed flat growth for the other producers in Southeast Asia and other parts of Asia. The once rapidly growing shrimp production is expected to be stable in the **Middle East and Iran**.

Using the estimated data for Vietnam and Indonesia, the production from Southeast Asia was down to 1.6 million tonnes in 2020, rising by 10% in 2021. A bullish 2022 was predicted (Figure 4).



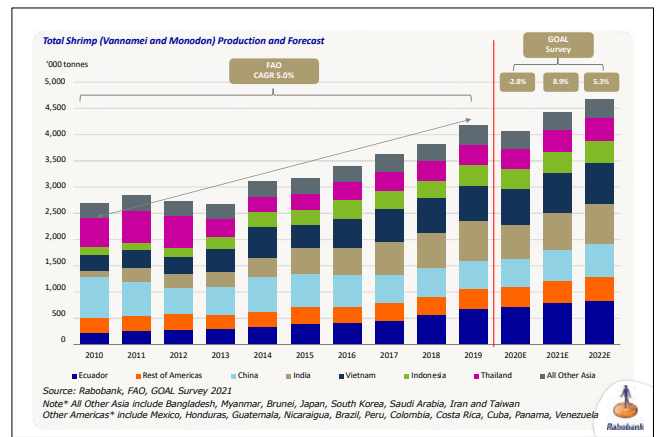
**Figure 4.** Southeast Asia: Shrimp production with estimated data for Vietnam and Indonesia

### Global forecast

The forecast using FAO data would give an estimate on global production (vannamei and monodon shrimp) at six million tonnes which industry sources say is too high. “I would prefer using the estimated data for China, Indonesia and Vietnam with a total of around four million tonnes in 2020 (Figure 5). A rebound by 2021 will raise this by 8.9% and a bullish 2022 will increase production by 10%. But this does not include the new data for Ecuador and Brazil, so the change may rise to 10% or more for 2021,” said Nikolik.

### Export dynamics

This is a new chapter for the survey report. The top six exporters are India, Ecuador, Vietnam, Indonesia, Thailand and China. In 2019, India was the top shrimp exporter, in terms of value and volume. The volume of 532,000 tonnes was just marginally above that for Ecuador at 528,000 tonnes. Dynamics changed in 2020. Ecuador outperformed India and was the world’s leading



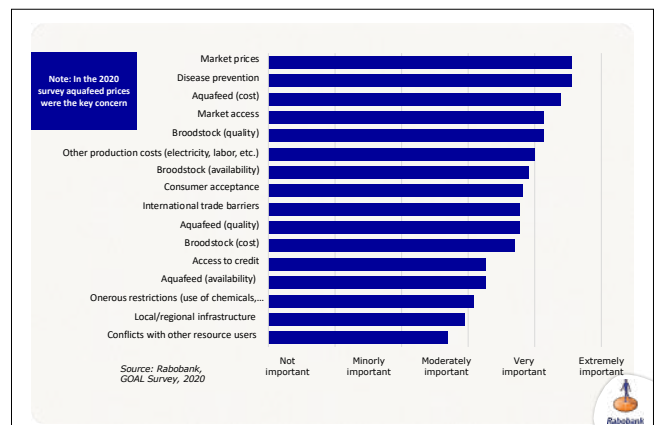
**Figure 5.** Global shrimp production estimates (vannamei and monodon shrimp) using estimated data for China, Vietnam, Indonesia.

exporter by volume but by value, India was still the leader because it was exporting processed products. In YTD July 2021, Ecuador exceeded India both by volume and value, which is related to Ecuador focussing on US and EU markets where the demand was on value added products. In the first half of 2021, export volumes from Ecuador, India and Vietnam were up, showing a recovery in demand. “These numbers justify the huge production figures in Ecuador.”

### Concerns in 2021

This year, the response to the question on whether the global market will strengthen in 2021 compared to 2020, was a positive “yes”. The respondents also agreed that the global economic conditions will be better in 2021 as compared to 2020. “However, as expected, there was disagreement that feed prices will be lower as compared to 2020,” noted Nikolik.

When it came to key concerns, whereas aquafeed price was top on the list in the 2020 survey. In 2021, the top main concern was on market price, followed by disease prevention and aquafeed cost.



### Conclusion

Looking to 2022, Nikolik summarised that it is expected to be a strong supply year, up 5.3% from the volumes in 2021. The CAGR for 2011–2020 is 4.0%.



## Balancing aquaculture production and consumption

### Part 1: Ecosystem management and innovations to address future challenges

The 26<sup>th</sup> DSM aquaculture conference Asia Pacific was about balancing aquaculture production and consumption. The virtual conference, held on November 23-24 2021 comprised of presentations and aquabytes – short clips on industry issues. Day 1 was dedicated to presentations focusing on ecosystem management and the drive towards sustainability. Day two featured technical presentations on gut health, making an impact with feeding strategies and increasing productivity in intensive shrimp farming.

In his welcome address, **Achyuth Iyengar**, Regional Director, ANH, said, “Global aquaculture production will continue to increase as the demand for healthier sources of protein continue. As a result, nutrition and feeding play a central and essential role in the sustainable development of aquaculture. For this to happen, balancing is key to promoting sustainable consumption on one hand and production on the other. We believe ecosystem management is the way forward to address the challenges that lie ahead.”

The way DSM approaches balancing aquaculture production and consumption is through its sustainability business drives. “We classify these into three elements; above water, the water itself and below the water. With above the water, expanding the role of aquaculture towards ending hunger and malnutrition is as important a focus as increasing production. Hence, we focus on providing solutions around antimicrobial resistance, a critical business driver.

“Water quality of limited resources is under constant pressure. Current aquaculture inland production

represents more than 50% of total global production, with the dominant species comprising the carps, tilapia, catfish and shrimp. We have innovative solutions to reduce phosphorus and nitrogen emissions and other critical business drivers. We do this by making efficient use of natural resources through better digestibility of those nutrients. The health of farmed fish and shrimp is essential to guarantee sustainable and profitable growth of aquaculture. By ensuring optimal nutrition and gut health, we can improve the lifetime performance of farm animals.”

### Sustainable business practices

Together with its 2021 theme, a critical aspect is “Unlocking the value of sustainable business practices”, said **David Nickell**, VP Sustainability and Business Solutions at DSM. Reducing the environmental footprint of animal protein production is much more than just reducing carbon emissions alone. The biggest impact on sustainability occurs at the farm level, driven primarily by feed production, digestion and excretion.



## NEXT ISSUES

### March/April 2022

Issue focus: Health & Disease Management  
 Industry review: Marine Fish  
 Feed/Production Technology: Fish Meal/Oil Replacements/  
 Offshore and Industrialisation/Innovations  
**Deadlines: Articles/Adverts – January 25**

### May/June 2022

Issue focus: Sustainable & Responsible Aquaculture  
 Feed/Production Technology: Sustainable Feeds/Hatchery  
 Technology/Innovations  
**Deadlines: Articles – March 15/Adverts – March 22Adverts**

Email: [zuridah@aquasiapac.com](mailto:zuridah@aquasiapac.com); [enquiries@aquasiapac.com](mailto:enquiries@aquasiapac.com) for details

The drive for sustainable animal protein demands accurate footprint measurements and improvements. For the animal protein industry to play a role in a balanced nutrition, it must be sustainable and operate with planetary boundaries. Nickell explained that the industry needs to increase production without expanding agricultural land, protect and restore natural ecosystems, reduce GHG emissions, food loss and waste.

“This is moving away from a siloed approach – which is product-driven, often based on the feed ecosystem and supplier perspective to a total ecosystem approach. With the latter, we need to show and measure the environmental footprint and how to improve with science-based solutions.” Nickell added, “But you do not improve what you do not measure. We know that feed accounts for 50-60% of production cost and 50-80% animal protein footprint.”

### **The value chain is driving change**

Here, Nickell identified three groups; regulators who look at new limits in farm operations, investors who want to ensure that they are investing in brands or companies sharing the same understanding of environmental footprint and have plans in place for improvement, and lastly, sustainability-conscious consumers who want to make a conscious decision on the products they buy. This requires labelling and understanding what a sustainable product is.

“Therefore, we see that change is evolving in the protein value chain, but these require tangible measurements. At the retail level, the examples are the eco score, footprinting of a product and front of pack score. Retailers are experimenting with consumer-focused sustainability food labelling, while the ESG investor community is looking at the risks and the EU is setting up subsidy payments linked to environmental KPIs.”

This switch to a more sustainable business requires funding. Green financing is being mobilised to pay for these changes and help businesses transition to a more sustainable future. “However, to access these financial instruments, they need to be able to measure the environmental footprint of their business down to the farm level. They have to put in place realisable business practices,” said Nickell.



*Having high ESG ratings is a good thing for a company. The whole idea is doing well by doing good, said David Nickell*

There is a substantial shift towards more ESG investing. The USD40 trillion FAIRR initiative, one of the world's fastest investor networks, focuses on animal protein producers and evaluates them on their 'protein producer index'. Aquaculture companies currently assessed are so far ranked as relatively low-medium risk.

“Having high ESG ratings is a good thing for a company. The whole idea is doing well by doing good. Higher ESG scores lead to lower costs of capital and debt. But again, to gain access to this requires incredible measurement for reliable, transparent data on the total environmental footprint and not only carbon measurement.”

### **Seafood sector**

To explain the situation at the retail level, Nickell used the consumer packaged goods (CPG) market in the US as an example. About 16% of the market is made up of sustainability marketed products. This is valued at USD 19 billion. Some 55% of the whole market comprise sustainably marketed products, which on average have a significant price premium of up to 40% over conventional products. Particularly in the seafood sector, there is increasing demand for sustainable products. Up to 30% of consumers are willing to pay more for products with certifications; ASC certified products achieve higher prices.

### **Footprint labelling and tracking**

At the consumer level, experimentation with food labelling and tracking is ongoing. Traffic light approaches, such as Nutri-score and Eco-score, are being tested by major retailers like Colruyt, Lidl and Carrefour in Europe. Here, the front of pack labelling shows the complete environmental footprint of the product, with a full environmental life cycle assessment (LCA). Consumers find it difficult to understand only carbon footprint impact. Some retailers experiment with mobile phone apps to track how sustainable the purchase is. The Eco-Score is based on LCA in 16 different dimensions of environmental impact and converts to points. There are additional points for certified products such as ASC or Label Rouge.



*Major Belgian retailer Colruyt is piloting Eco-Score on their private label 'boni' products. Shrimp are sourced from Ecuador, Costa Rica, Indonesia, Honduras, Vietnam, Saudi Arabia. On the left, peeled shrimp with ASC. Picture adapted from the presentation on unlocking the value of sustainable business practices by David Nickell.*

### **Understanding footprint data**

Too often, animal protein producers are judged on global averages of GHG footprint data. Nickell explained that the difference in scores is due to the system using

average category data, which means it is not picking up on producers that are producing at a very low footprint. “Producers are asking how to measure their environmental footprint in credible ways and when making changes, how to reduce it without negatively impacting production performance, cost and the return on investment.”

One of the most significant improvements is in nutrition, where up to 80% of the environmental footprint is linked. This is getting more out of less and using alternative feed raw materials with an inherently lower footprint. “Feed additives can make this happen as they bring that functionality into a diet and improve the productivity of the farming system. If this is done, you can unlock a significant value of sustainability.”

Nickell summarised, “Using advanced environmental footprinting services helps you understand exactly your footprint and where to make improvements. Reducing your environmental footprint and business risk is improving profitability.”

## Lessons to be learned across “aquacultures”

Aqua Investor and advisor at Norsk BioAkva, **Einar Wathne**, has seen the rise and fall of aquaculture globally over several decades. In “Lessons to be learned across ‘aquacultures,’” he presents his views. “According to Ragnar Tveteraas (2013), it is about growth curves of aquaculture, stagnation, declines and even death. Why do we see the different patterns and what are the underlying factors?” Tveteraas summed this up as managing external factors within aquaculture, mainly related to disease and fish health. It is the ability to relate to other sectors and users, exploit internal and external returns to scale and innovate.

In his presentation, Wathne compared the top two leading aquaculture industries, salmon (valued at USD18 billion in 2018) and shrimp (valued at USD26.7 billion in 2019, according to Fishsite.com). Both had a fantastic growth pattern from their start in the 1970s until today with millions of tonnes of production. An informal comparison on their ability to innovate, handle externalities (industry structure, organisation and governance) and on growth enablers such as capital was presented.

### Innovations

The salmon industry in Norway has a unique situation. “It has, maybe, the best political support of aquaculture globally - a ministry that has been promoting growth and not just executing control. It plans for industry development with targets into 2050, but growth ambitions have conditions. There are green terms where there will be no growth if these terms are not met. Then, there is the culture of dialogue with industry and science.” He added that the government has invested in R&D for more than 40 years. Today, the current focus is on commercialisation. It supports the establishment of industry clusters, mobilising capital for the sector and links corporates with entrepreneurs. Finally, the government is also involved in risk offloading for new technology by issuing research and development licenses such as ocean-based farming.



*Einar Wathne summed up his presentation as being about sustainability, people, planet and profitability, innovation, industrial organisation and governance.*

“Why do we not see the same innovation and success in shrimp? Firstly, many diverse countries are involved and the risk profiles are different. Shrimp farmers have not been seeking root causes but have approached problems in more opportunistic ways. Furthermore, there has been less access to R&D funding and they are less organised when driving collaborative efforts. Maybe there are differences in education levels in the industry. Finally, more scaling and risks have been left to private hands,” said Wathne.

He compared innovations. “While the salmon industry is now focusing on higher technology; land-based recirculation systems and offshore farms, the shrimp industry is still debating on farming models - extensive Latin American model, the more intensive model or recent super-intensive advanced models.”

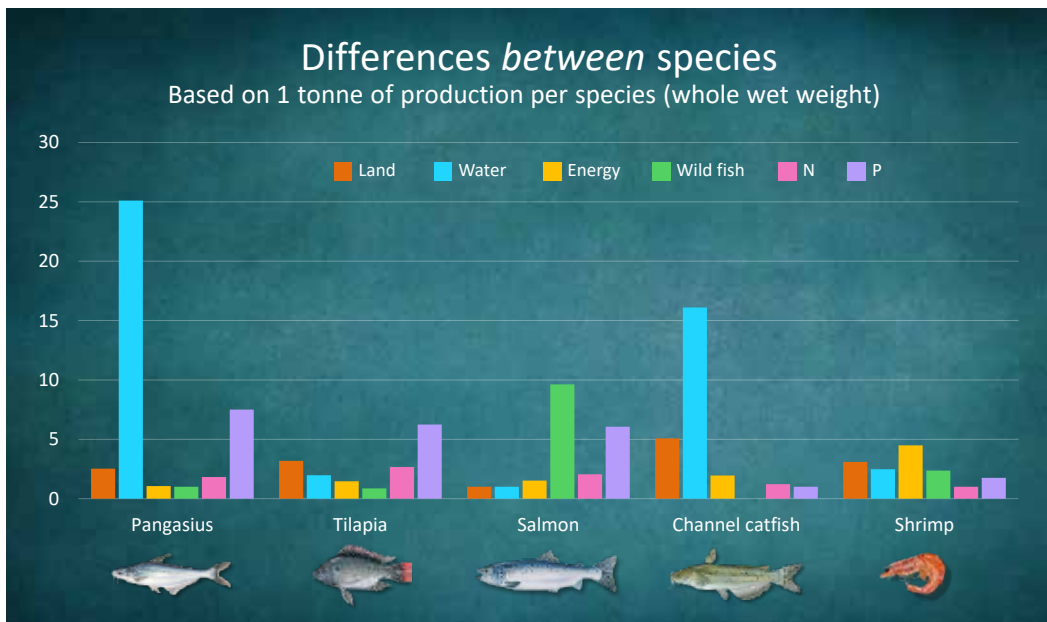
Another area of innovation is feeding and digitalisation. Here, salmon farming focuses on monitoring individual fish using cameras to identify diseases and individual growth. At the same time, the shrimp is debating on automatic feeders vs manual feeding. In genetics, the shrimp industry is looking at advanced breeding programs and multiplication centres, whereas the salmon industry has been practicing SNP-based selection to reduce diseases such as the severe viral disease, infectious pancreatic necrosis (IPN).

“Relating to innovations, I recommend looking at the industry level, not at the company level, define innovations in major focus areas, drive collaborative initiatives, through industry-led consortia crossing country borders, include the supplier industry in research programs and work closely with start-up communities.”

### Industry structure organisation and governance

Wathne compared the value chains and their organisation. The shrimp industry has seen faster growth but has also shown a boom-and-bust cycle. There is less vertical integration and consolidation to deal with risks. Farming, processing, export and import segments are less structured. “New technology exists but the uptake is low or uneven, and overall, there is a weak ability between producers to coordinate risk leading to a dominance by processors over producers,” said Wathne.

In contrast, while the salmon industry is challenged by disease, pollutants, parasites and environmental issues, the positives are a high level of standardisations with one species (namely the Atlantic salmon) and a few countries. Consolidation of companies drives the economy of scale, helping to reduce risks. There is vertical integration, systematic stakeholder identification and management with pre-competitive collaboration.



**Figure 1.** Differences between species based on a tonne of production per species (whole wet weight).

The salmon industry has a common goal to adhere to the ASC standard achieved via the Global Salmon Initiative (GSI). More than 50% of players are participating and are involved in the supply segment. The results are that ASC has around a million tonnes of certified salmon compared to 200,000 tonnes of shrimp.

“What should we learn from this? We can promote spokespeople as thought leaders and present challenges and solutions in the political, UN and NGO arena. We can define a common industry sustainability ambition and seek long-term solutions, not opportunities. Two other recommendations are to establish a GSI-shrimp and encourage and promote certifications.”

#### **Funding and access to capital**

Both industries need capital for growth. While WWF recommends the three financial sources; buyers and retailers, impact investors and international financial institutions within the shrimp industry, Wathne added access to local capital, industrial investors and international skilled aquaculture investors. “One example is Grobest which has established the Gro Farm model, to convert to more intensive farming systems by providing know-how and feed but also capital through their local distributor network and local banks. This is a very strong tool for conversion locally.”

Many of Norway's leading salmon farming companies are listed on the Oslo Stock Exchange. “Is this available for shrimp? It is not there yet, but the Euronext Growth index has just been established. In 2021, there were 11 new listings of both companies, which included kingfish and, most recently, Asian seabass. There are opportunities but remember these are skilled investors.”



Aaron McNevin asked, “Should consumers have a choice on sustainable products or should all choices for them be more sustainable?”

Lessons include a need for the investor community to become the main stakeholder in the shrimp industry. “We need to promote the industry at forums, attract institutional investors, use available marketplace for listing, seek support from impact investors.”

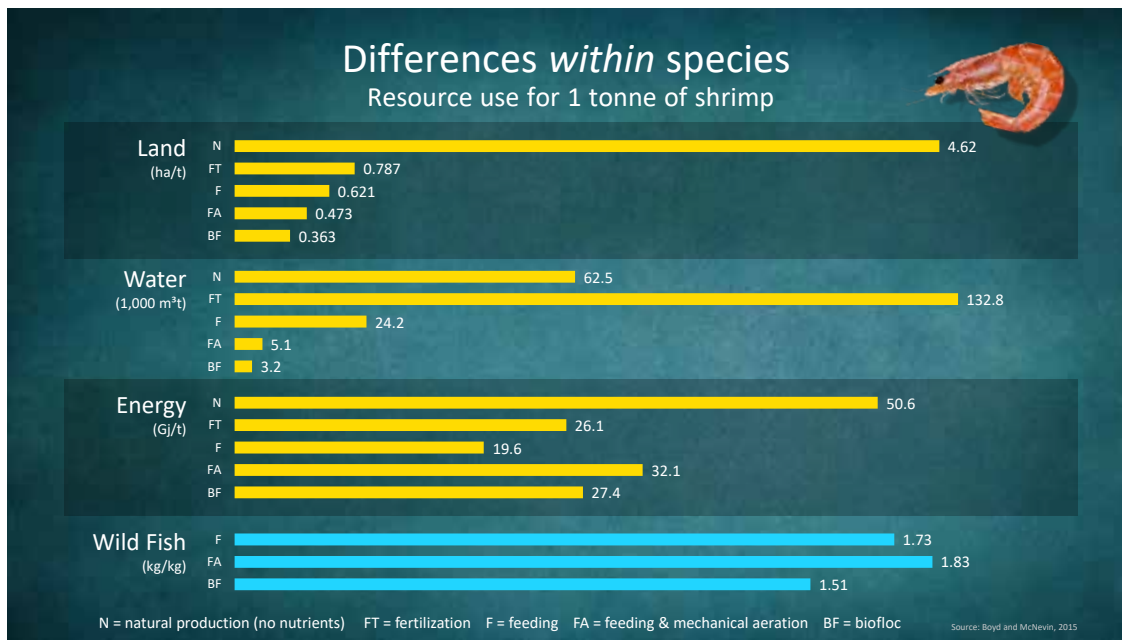
Wathne summed up his presentation as being about sustainability, people, planet and profitability, innovation, industrial organisation and governance. “I have proposed a few key initiatives that can be learned across both industries.”

### **Natural resource use in Asian aquaculture**

By 2050, the increase in daily protein demand per capita will be 15.3% for developed countries, 103.6% in developing countries and 69.2% in least developed countries. WWF's **Aaron McNevin**, Global Network Lead, Aquaculture, said, “The trajectory indicates that we will become more resource scarce. Therefore, we must produce more with less. We must accelerate the level of efficiency. But who is going to do this?” McNevin was clear that it is not a choice, but it is the responsibility of all stakeholders.

Food production uses 38% of land and much of this is inefficiently used. WWF has reached out to global producers and the estimate is that 6% of global shrimp production is from extensive systems using 46% of 2.4 million hectares of land area. “In a world of scarce resources, this level is simply unacceptable,” McNevin said. “The value proposition is also not to encroach into natural ecosystems which are necessary to combat climate change. Land costs and clearing are major operating costs. We know that if shrimp/fish survive well, we are using our resources well. Less feed with better feed conversion ratios (FCR) means lower feed costs.”

McNevin said the different species will have different uses of resources (land, water, energy, wild fish; figure 1). “There are no silver bullets nor perfect species. Consumers have different demands but there are better species which use less of resources such as water. It is not only species but also within a species and systems.”



**Figure 2.** The differences within species of resource use for one tonne of shrimp for various systems. (N=natural production (no nutrients); FT = fertilization; F = feeding; FA = feeding & mechanical aeration; BF = biofloc) Source: Boyd and McNevin, 2015.

Boyd and McNevin (2015) recognised that for the shrimp, resource use varies with systems (Figure 2). “Therefore, we should be conscious of species, resource use and the tradeoffs.”

McNevin noted that in some species, system intensification gives increased output when land expansion is not feasible. Culture technologies have advanced a great deal. In aquaculture, water quality management is a must but globally, water quality is being degraded and actions are necessary. Discharging less effluent also means less introduction of disease vectors.

“Food production produces 25-35% of GHGs. We are clear that the major hotspots for climate change are at the farm level and feed supply chain. WWF has ongoing work to determine the hotspots, such as energy use for aeration where we can match equipment with the right horsepower. Technology is improving for better output and we can help farmers to equip themselves with better equipment.” McNevin suggested promoting the use of factory-made paddle wheel aerators rather than relying on farm-made models. “We also need to realise how much consumers push farmers with margins, to cut corners to skimp and save.”

In summary, there are environmental benefits from better practices with site designs, chemical use, feed and intensification to either lower or lessen GHG emissions.

**Wild fish**

Food production uses 23% of marine resources globally. FCR and its impact on costs and natural resources were discussed. The business cost of reducing FCR by 10% and the global impact on feed use, costs, resources and fishmeal and fish oil were presented in Table 1. “We can be looking at more than a hundred million of savings at the farm level, million joules of energy saved, thousands of hectares saved, water saved and a dramatic volume of wild fish. We can match the value proposition of costs savings with efficient use of natural resources. From the farmer’s perspective, it is the efficient use of feeds.”

**Climate change and food production**

McNevin sees this as a paradox with challenges. “This is a plea to think about ways to be efficient and not to skirt around issues. Essentially, we should ask, ‘should consumers have a choice on sustainable products or should all choices for them be more sustainable?’”

	Feed production (tonnes)	Feed saved (tonnes)	Savings (USD million)	Energy conserved (GJ)	Land conserved (km²)	Water conserved (km³)	Wild fish conserved (tonnes)
Ictalurid catfish	419,215	41,922	21	205,419	77	0.05	0
Tilapia	3,374,000	337,400	317	2,180,420	1167	0.63	74,800
Pangasius	1,161,938	116,194	93	619,314	259	0.14	70,065
Atlantic salmon	2,087,111	208,711	271	2,604,713	303	0.18	601,088
Rainbow trout	837,000	83,700	105	1,026,162	69	0.04	192,426
Whiteleg shrimp	2,817,962	281,796	282	2,555,890	702	0.31	230,509
Black tiger shrimp	563,815	56,382	62	599,904	131	0.06	73,409

**Table 1.** The global impact of reducing FCR 10% - feed use, cost, resources, and wild fish (meal & oil). Extracted from McNevin 2021. Source: Chatvijitkul, S., Boyd, C.E., Davis, D.A. and McNevin, A.A., 2017. Embodied resources in fish and shrimp feeds. Journal of the World Aquaculture Society, 48(1), pp.7-19.

## Latest in smart fishery and ocean sustainability solutions



There were more than 100 exhibitors from 15 countries displaying their latest innovations and products in line with the “smart fishery and ocean sustainability” theme at the Taiwan International Fisheries and Seafood Show 2021. This was a hybrid event at the Taipei Nangang Exhibition Center, Hall 2 held from December 2 to 4, 2021.

Organisers said that countries represented at the event were Taiwan, South Korea, China, Vietnam, Indonesia, Malaysia and nine others. They displayed their innovative products and solutions in areas ranging from smart fishing technology, ocean sustainability management to healthy and eco-friendly seafood.

H.E. Ambassador of Embassy of the Republic of Nicaragua, Mirna Mariela Rivera Andino, and Budi Santoso, Representative of Indonesian Economic and Trade Office to Taipei (IETO) also showed their support and to popularise the seafoods from Nicaragua and Indonesia, respectively. Sulistyono, Director of Trade department at IETO indicated that Indonesia has joined the show for six years and will keep participating to introduce the best seafood to the Taiwan market.

Organised by Taiwan External Trade Development Council, TAITRA and My Exhibition Co., Ltd., the 7th edition of TIFSS is Taiwan’s exclusive B2B and tailored trade show for the fishery industry, with four exhibition themes: marine intelligent technology and fisheries equipment, smart aquaculture and fish breeding technology, seafood & value-added processing and fishing tackle & water equipment. All these showed Taiwan’s strong industrial energies, latest technologies as well as innovation powers.

Highlights include the innovative buoy that combines the traditional fishing net buoy and AIS system to detect the actual location and condition of the fishing net immediately;

the smart aquaculture program with IoT and AI technologies, which can be installed on the mobile phone, for the user to get the real-time status of the culture pond; the official certified seafood from Penghu, Taiwan, with strict quality control to be natural, fresh and sweet; and the floating device with foam material technology that is lightweight with high buoyancy.

Various highlight events were arranged both online and offline, including one-on-one procurement meetings, new product launches and international forums to maximise the business cooperation and interaction between exhibitors and visitors regardless of the limitation of time and boundary.

In response to the restriction on travel, organisers arranged for TIFSS 2021 Online, the month-long virtual show (December 2-31) for those unable to visit the show physically. With the advanced digital platform, visitors can browse the 360° and 720° product catalogues from more than 100 exhibitors around the globe and leave a message or arrange an online meeting anytime. [www.taiwanfishery.com](http://www.taiwanfishery.com)



# The Second Marine Aquaculture Technology Forum

This was a half day conference organised in conjunction with the annual Taiwan International Fisheries and Seafood Show. The aim of this hybrid event was to enhance the interaction between the international and Taiwanese industry and academia. In his introduction, Dr Yew-Hu Chien, National Taiwan Ocean University (NTOU), said that despite the circumstances with this pandemic, it was fortunate that organisers could gather speakers and conference attendees for this second forum. Topics included innovative technologies in pond environment management, feed and nutrition, health management, inline with the conference theme of “Towards profitability during pandemic.”

Speakers were from Thailand, Spain, France, Myanmar and Taiwan. The conference was supported by various organisations in Taiwan, including The Council of Agriculture (CoA), NTOU and the Fish Breeding Association (FBA). The gold sponsor was Adisseo and the silver sponsor was Ynsect.



Over the past five decades, the drivers of innovation in aquaculture have been to enhance productivity at the hatchery and farm levels, controlling diseases, climate change, improving food safety and animal welfare and better environmental control and managing resources efficiently. **Dr Krishna R Salin**, Chair, Aquaculture Program at the Asian Institute of Technology said, “The challenges are coping with the new normal with disruption in aquaculture production and consumption, need for social distancing, reduce human interventions and have remote operations. Then it is integrating this digital technology which reaches half of the population in developing countries. Digital technology has grown from a mere use of internet skills to cognitive learning.”

Salin added that the future for aquaculture is pathbreaking technologies (IoT, AI and blockchain) to move aquaculture from a traditional system to automation. Innovations already applied are smart sensors and real time water quality monitoring in fish and shrimp farms. “A large impact on aquaculture in Asia has been on feed management; moving from automatic feeders to precision feed delivery with smart feeders and acoustic sensors. This may be more widespread in the future with less demand on labour. Intelligent feeding systems where AI is integrated with analysis of data and counting feed pellets as is used for the salmon are slowly coming to Asia. Nanobubble technology is also now applied in aquaculture.”

In terms of challenges, Salin added, “Automation does not mean being intelligent. The ability of small farmers to

adopt innovations is still limited and often beyond their financial capacity. There is also farmer’s apprehension on efficiency and data ownership. There is a skill divide and governments can only help to facilitate since most innovations have been developed by private groups. Nevertheless, smart technology driven production and consumption is the future of aquaculture but how well they are integrated with sustainable production models is the biggest challenge.”



Guillaume Daoulas, Business Development Director, Ynsect, France on Mealworm meal: A premium sustainable animal protein resource for aquafeed

Founded in 2011, Ynsect breeds mealworms, transforming them into 70% protein meals as well as other premium ingredients. Ynsect now has factories in France, The Netherlands and in Miami, USA. Recently it raised USD 550 million. It works with mealworms because it has easy access to feed stock, said Daoulas. The pilot factory in France is fully automated, using robotics and AI and produces 1,000 tonnes/year of products. Coming up soon is 45,000m<sup>2</sup> plant in Amiens, France, which will be producing 100,000 tonnes of all products, when it comes on stream at the end of 2022. “By the summer of 2023, we expect to produce 25,000 tonnes of the protein Yn meal, which should alleviate aquafeed industry concerns on availability of protein meals,” said **Guillaume Daoulas**.

“We are first with carbon negative vertical farming. At Sparos, we have done trials with the rainbow trout where the premium fishmeal component was gradually replaced with the Yn meal. The group with total replacement of fishmeal stands out in terms of growth performance. Bodyweight gain was 33% and feed conversion ratio (FCR) was 15% lower.

“In the trials conducted at Kasetsart University in Thailand with the white shrimp, we started with 30% fishmeal diets and began replacing the fishmeal. The best results were with a mixed of fishmeal and our Yn meal diet, FCR improved by 25% and survival by 60%.” Daoulas added the immune benefits were clear in a challenge test against *Vibrio parahaemolyticus*.

A recent trial with the European seabass also showed lowering of FCR by 25–33% and less mortality by 25%. Ynsect is also working with two meal worms – *Tenebrio molitor* and buffalo mealworm which can give aquafeed millers two options as feed ingredients. On the amino acid composition and the concern with taurine as essential for marine fish, Daoulas said that its protein meal has 0.42% taurine as well as other amino acids.

“With these good trial results, we want to be global, and the next step is to identify strategic partners in East and Southeast Asia such as from Taiwan, Japan and Korea.”



Professor **Han-Jia Lin**, Founder, Giant Biotechnology Inc., Taiwan described the development of an alternative antibiotics for aquaculture using the novel herbmedotcin technology. “We seek alternatives to antibiotics, especially from natural sources. This technology has its roots in traditional Chinese herbology. As a new-generation protective agent, Herbmedotcin™ followed evidence-based guidelines, with pre-clinical trials on rats. This is a therapeutic carbon nanomaterial made from food grade materials and is efficient at killing bacteria. It is disruptive antibiotic alternative.”

Herbmedotcin is a therapeutic agent against white spot syndrome virus (WSSV) in *Litopenaeus vannamei* and recent research is on its effects against AHPND. In phase 2, there was small-scale research with tilapia, groupers and shrimp, respectively, which showed that small doses of hermedotcin worked against marine pathogens and gave better survival. Phase 3 was a large-scale field trial in Tainan, Taiwan. Lin said that despite that these were open ponds, survival was 50% more than with conventional feeds. In 2020, Phase 4 was post market surveillance in a farm in Pingtung where harvest of shrimp fed feeds containing hermedotcin was double that of the control pond. There was no disease outbreak. In 2019, the technology was transferred to a university startup Giant Bio which officially launched the products. It raised TWD 25 million (USD 940,000) from strategic investors.

“Today we have 100 users in Taiwan, 3.5% market share and 65% repurchase rate. Our achievement was the success in high density black tiger shrimp farming in Taiwan.”



“Tilapia produced in seawater have better taste because of the anabolic metabolism of fatty acids and free amino acids such as proline metabolic pathways,” said Associate Professor **Chang-Wen Huang**, Department of Aquaculture, NTOU. Taiwan’s annual tilapia production is small at only 70-80,000 tonnes of which 12-21% are in saline environments. Huang described the genetics selection work with the participation of teams at NTOU and a private hatchery in Tainan. Published reports are on maternal and paternal inheritance analysis for species identification. In their work on salinity tolerance, they

gradually increased salinity of tank water to ~33ppt at ~5ppt per 15 min. Digital imaging AI was used to detect abnormal behaviour.

Huang concluded that the specific markers developed in this research can be used for identification of genetic polymorphism and salinity tolerant traits in Taiwan tilapia. The genetic control of important performance and production traits must be understood. Such precision genetics and breeding technologies for marker assisted selection, genome selection or genome editing must be further developed to apply to quality-based fry production.



Dr **Nyan Taw**, Shrimp Aquaculture Consultant, said that biofloc technology is the blue revolution as he delved into its use in many shrimp farms across the globe. “The main economic benefits of biofloc systems are better biosecurity, lower FCR (1.0-1.2) and higher production (>50 tonnes/ha). Culture duration is shorter. In terms of energy, biofloc systems use more energy combined with high production the energy efficiency rises to 680-1,000kg/ha.” He added that it produces probiotic bacteria *in situ* for better immunity and disease control. There is self-nitrification and with zero water exchange, there is the prevention of disease entering the pond system. His experience was production of dark vannamei shrimp which meets market demands for red colouration in cooked shrimp.

Nyan gave the ten points for using biofloc in basic management concepts in shrimp culture. Aerators keep the pond water in suspension and positioning of aerators and numbers are important for best results. “Back in 2005 in Indonesia, we already knew that excess sludge control is essential especially for full biofloc systems and has to be removed physically or by vacuuming. Biofloc systems have to follow carrying capacity of the pond.”



“With functional ingredients, we can target environmental and economic sustainability and, farm management, and environmental practices. These are four out of the six criteria established by the World Bank for sustainable aquaculture,” said Dr **Waldo Nuez-Ortin**, Lead Scientist Aquaculture Adisseo, Spain as he focussed on the company’s three programs for a more sustainable production of marine fish.

## Is learning part of your daily routine?

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This is What Most People Think of When "Raceways" are Discussed

Atlantic salmon THR requirement

- Starting fish weight = 15 g
- Weight gain and THR gain increased with THR intake up to a point (graph inflection point)
- The efficiency of uptake was slightly higher with the deficient diet (3.1 g/kg)
- Optimum THR level was 33 mg/kg weight gain/die

Early efforts on IPRS technology were started in the United States of America, and this is the origin of the concepts that have developed into the IPRS systems of today

The palatability program promotes environmental and economic sustainability by optimising fishmeal use and reducing formulation costs. The digestion program promotes environmental sustainability by giving flexibility to the formulator to use alternative ingredients and an economic impact when feed costs are reduced. The health program reduces dependence on antibiotic use and other chemicals that can disrupt the ecosystem while improving biomass and profitability.

Traditional attractants are under pressure. When we substitute feed ingredients. When we reduce fishmeal in feeds, we reduce the functional protein fraction in fishmeal – for each 10kg of fishmeal, there is only 0.5kg of functional protein to support fish health and feed attractability. The objective of the palatability program is to improve attractability of low fishmeal diets.” Nuez-Ortin gave an example of reducing fishmeal inclusion from 20% to 10% in gilthead seabream *Sparus auratus* and supplementing the low fishmeal diet with a peptide concentrate Aquabite. The peptide concentrate compensated in terms of weight gain (+15%), SGR (+9%), PER (+7%) and FCR (-5%) as compared to diets with 10% fishmeal only.

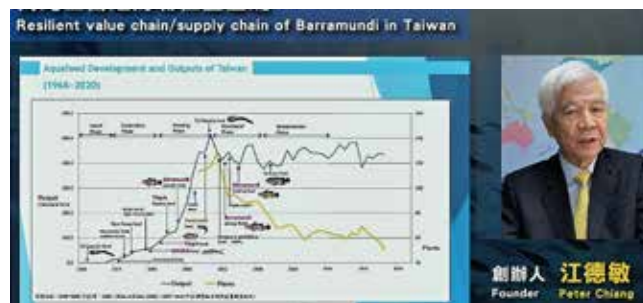
When fishmeal and fish oil are reduced, cholesterol and phospholipids become limited. “In the digestion program, we optimise the absorption of these nutrients and improve the emulsification of fat with digestion and metabolic enhancers. We can reduce formulation costs and compensate digestion and metabolic disturbances during less optimal production conditions. The more research we do, we show that benefits go beyond emulsification such as increased delivery of nutrients from the intestine and increase in metabolism of lipids, carbohydrates and amino acids.

“In the health program, the focus is not only on anti-microbial and anti-parasitic, but we also support gut health. When we successfully prevent and reduce the severity of infections, we will positively impact survival and growth.” Nuez-Ortin showed how seabream infected with *Enteromyxum leei* fed diets supplemented with the phytobiotics-based health additive SanacoreGM were able to maintain feed intake and therefore better growth. The additive also has anti-inflammatory properties and promotes gut integrity.



Speakers and some leaders in Taiwan's aquaculture industry with Dr I-Chiu Liao (centre), Allen Wu, Regional Manager – Aquaculture, Asia Pacific, Adisseo (third left), Professor Shi-Yen Shiau, NTOU (fifth left), Dr Yew-Hu Chien and back row, Hsiang-Pin Lan, Asia Marine Aquaculture, US Soybean Export Council.

Nuez-Ortin concluded that in terms of carbon footprint, a life cycle assessment can demonstrate that increasing feeding efficiency has a positive impact in reducing the carbon footprint/kg seabream produced in the Mediterranean. The main hotspots are feeds and energy. The carbon footprint without the additive was 7.8kg CO<sub>2</sub>/kg seabream, due to feed. Under a 10% improvement in FCR due to reduced mortality, the reduction in CO<sub>2</sub>/kg is between 5-6% depending on the pressure of disease.



**Peter Chiang**, Founder, HANAQUA Tech Inc., Taiwan, noted that today, the resilience of the Asian seabass or barramundi is because of the integration of segments of the value chain: 7 hatcheries (producing 500 million fry/year), 1,000 ha of farms (producing 50,000 tonnes of 400g to 3kg fish for markets), 5 processing plants and 14 feedmills.

The industry depends on fertilised eggs imported from Thailand over the winter season and grown to fingerlings ready for stocking in early spring. This gives farmers a head start in its grow-out. Initially, compound feeds were moist feeds with vitamins and minerals added. Hanaqua started producing feeds for the barramundi in 1986, and then produced sinking pellets in 1993 and floating pellets in 1995. “Today, we have more than 100 farmers using our feed and sales volumes are 8,000 tonnes. Our market share is 20-25%. Taiwan used to have 200 feedmills which declined to only 51 in 2020. Feed accounts for 60% of production costs”

Mainly family based, Chiang noted that most in the supply chain have low break-even point (BEP) but can have a favourable market structure. “The local markets consume 70% of production and with the pandemic and online marketing, more product forms have emerged. Hatcheries have a unique grow-out model using both imported and local sources of fingerlings. With phased culture strategies, farmers can easily reduce the impact from market fluctuations to maximise profits.”

“We have started using IoT and AI during production for environmental and cost control and feed management. Under the GreeNaqua model, we use solar energy produced onsite, to reduce carbon emissions. Using this model for barramundi production is compatible to the UN's SDGs,” added Chiang. “An added bonus, is that in Taiwan, barramundi farming is a circular economy because we have the ability to use all parts of the fish, including skin and scale for collagen, and viscera for fish meal.”

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The 13th Asian Fisheries and Aquaculture Forum (13th AFAF) is a scientific forum organised by the Asian Fisheries Society (AFS) once every three years to understand the global trends and addressing issues faced by the fishery and aquaculture industry. The main purpose of this forum is to provide an international platform for eminent scientists and young researchers from around the globe to share their research experiences and innovative ideas. This forum brings in a wide variety of knowledge and expertise to address key issues towards developing sustainable fisheries and aquaculture. In view of the prevailing global Covid-19 pandemic, we have decided to organise the 13th AFAF as a virtual forum from 31 May 31–June 2.

The “3S principle” (*Sustainable Fisheries, Smart Aquaculture, and Splendid Future*) theme of the 13th AFAF conveys the core idea of the conference, which is to create a splendid future by improving sustainable fisheries and incorporating smart technology in aquaculture. This forum will provide a platform for the research community to discuss key issues relating to several SDGs and to share their progress, technical innovations, and knowledge.

This virtual forum aims at providing an equal opportunity for all participants to interact with the experts to get valuable insights on sustainable fisheries and aquaculture. <https://13afaf.tw/index.php>



## EDITORIAL CALENDAR 2022

Look out for AAP's annual report on trends in Asia's production of marine shrimp and aquafeeds

Volume 18	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec
<b>Deadlines - Technical articles</b>	January 25	March 15	May 17	July 12	September 13
<b>Deadlines - Advert Bookings</b>	January 25	March 22	May 24	July 19	September 20
<b>Innovations/ Startups</b>	Experiences and opinions covering role models; clear and present needs of industry; innovations and digitalisation in aquaculture				
<b>Interviews with industry leaders</b>	Focus in 2022 will be leaders pushing for sustainable aquaculture				
<b>Issue focus</b> Emerging trends and challenges	Nursery & Hatchery	Health & Disease Management	Sustainable & Responsible Aquaculture	Aquaculture Innovations	Health & Disease Management
<b>Industry Review</b>	Marine Fish	Aquafeed Production	Tilapia	Marine Shrimp	Catfish & Freshwater Fish
<b>Feeds &amp; Processing Technology</b>	Fish meal/oil Replacements	Sustainable Feeds	Functional Feeds/ Additives	Novel Ingredients	Feed Enzymes/Post Pellet Applications
<b>Production Technology</b>	Offshore and Industrialisation	Hatchery Technology	Real Time Monitoring/ Big Data	Feed management	Post-Harvest Processing
<b>Marketing activities</b>	Market and product developments, generic marketing, certifications, branding, food safety etc				
<b>Company/Product News</b>	News on activities at international, regional and local conferences and trade shows				
<b>Events</b> <i>Distribution at these events as well as local and regional meetings</i> <b>*Show preview</b>	<b>RAStech 2022</b> South Carolina, USA, March 30–31	<b>World Aquaculture 2021</b> Merida, Mexico, May 24–27	<b>TARS 2022</b> August 16–18	<b>Aquatica Asia,</b> Jakarta, Indonesia November 9–11	<b>*World Aquaculture Singapore</b> November 29–December 2
For advertising/article contributions, and guidelines contact: <a href="mailto:zuridah@aquasiapac.com">zuridah@aquasiapac.com</a>	<b>Aquaculture Africa</b> Alexandria, Egypt, March 25–28	<b>13 Asian Fisheries Aquaculture Forum</b> Tainan, Taiwan May 31–June 2	<b>Diseases in Asian Aquaculture (DAA11)</b> Kuching, Malaysia, August 23–26 (Hybrid)	<b>Aquaculture Europe 2022</b> Rimini, Italy September 27–30	
	<b>Seafood Expo Global2021</b> Barcelona Spain April 26–28		<b>*Nutrition and Health Asia/Victam 2022</b> Bangkok, Thailand September 7–9		



## Sustainable Aquaculture – Feeding Africa

AQUACULTURE AFRICA 2021  
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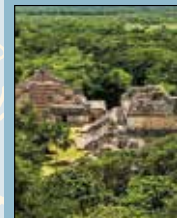
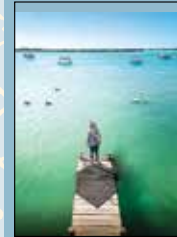
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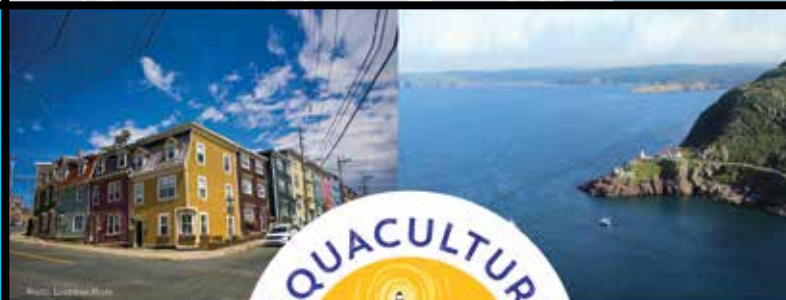
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## 31st Annual Practical Short Course on Feeds & Pet Food Extrusion

January 31– February 4, 2022

As several events continue to be postponed, moved online, or cancelled altogether because of Covid-19 concerns in the United States, Texas A&M University (TAMU) has announced its 31st Annual Practical Short Course on Feeds & Pet Food Extrusion, will be held in hybrid format for those who like to attend face to face and for those who still cannot travel because of COVID pandemic.

A one-week Practical Short Course on Feeds & Pet Food Extrusion will be presented on January 31- February 4, 2022, at Texas A&M University in hybrid format by staff, industry representatives, and consultants. The program will cover information on different extrusion systems such as Dry extruder, Expander, Single and Twin-Screw extruder, designing new feed mills and selecting conveying, drying, grinding, conditioning and feed mixing equipment. Current practices for production of pet foods, preparing full-fat soy meal; recycling by-products and secondary resources; spraying and coating fats, digests and preservatives; use of encapsulated ingredients and preparation of premixes are reviewed. Participants can register online at <https://cvent.me/44O2ae?RefId=TEES+Edge+Website>

## AQUACULTURE 2022

### Covid Update

AQUACULTURE 2022 is the triennial international event organised by the World Aquaculture Society in San Diego, USA from February 28 to March 4, 2022. This is going ahead as an in-person meeting. There will not be a virtual component available for the meeting. As the Covid situation changes all the time, we will not set final protocols until about the first week of February. *There are no plans to cancel the meeting or make it virtual.*

At the moment, the only restriction in San Diego is wearing masks indoors. The protocols for AQUACULTURE 2022 will reflect the latest information and guidance from CDC, other experts and any State guidelines/restrictions. Potential requirements include wearing masks and safe distancing. There will have masks and individual sanitiser available too.

From registrations and previous meetings, nearly 95% of attendees are fully vaccinated which is the best precaution. Organisers urge anyone attending the event to get fully vaccinated and boosted.

Most experts feel that the Omicron variant course will run about 6 weeks and start tapering off. So, WAS is hopeful that things will improve around the first of February. Already some restrictions around the world are being lifted.



## AQUACULTURE AFRICA 2021

March 25–28, 2022 – Alexandria, Egypt

March 25 would be the day of registration and exhibitors moving in and farm tours. March 26, 27, 28 is for the conference and the trade show and of course all the extra workshops, business meeting and staff meetings. Updates are on the web. Registration is open. Complete the online registration form. Submission of abstracts and full papers has now been extended to **February 15, 2022**. All abstracts already submitted are valid and will be processed accordingly. Limited space is available for interested tradeshow exhibitors. Contact: [mario@marevent.com](mailto:mario@marevent.com); Web [www.was.org](http://www.was.org)



# 2022

**February 28–March 4**

Aquaculture 2022  
San Diego, USA  
[www.was.org](http://www.was.org)

**March 30–31**

RAStech 2022  
South Carolina, USA  
[www.ras-tec.com](http://www.ras-tec.com)

**April 25–28**

World Aquaculture 2022  
Qingdao, PR China  
[www.was.org](http://www.was.org)

**April 26–28**

Seafood Expo Global  
Barcelona, Spain  
[www.seafoodexpo.com/global/](http://www.seafoodexpo.com/global/)

**May 24–27**

World Aquaculture  
Merida, Mexico  
[www.was.org](http://www.was.org)

**May 31–June 2**

13 AFAF – Asian Fisheries  
Aquaculture Forum  
Tainan, Taiwan  
<https://13afaf.tw/index.php>

**August 23–26**

DAA11  
Kuching, Malaysia  
[www.daa11.org](http://www.daa11.org) (Hybrid)

**September 7–9**

Nutrition and Health Asia/  
Victam 2022  
Bangkok, Thailand  
<https://victamasias.com/>

**September 13–15**

SPACE  
Rennes, France  
[www.space.fr](http://www.space.fr)

**September 27–30**

Aquaculture Europe 2022  
Rimini- Italy  
[www.aquaeas.eu](http://www.aquaeas.eu)

**November 9–11**

Aquatica Asia  
Jakarta- Indonesia  
<https://aquaticaasia.com/>

**November 29–December 2**

World Aquaculture Singapore  
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