SUSTAINABLE MONOSEX FARMING OF GIANT FRESHWATER PRAWNS IN MALAYSIA: PATHWAY TO A CARBON RESILIENT INSULAR PROTEIN ECONOMY (CRIPE)

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The CRIPE model (Carbon Resilient Insular Protein Economy) is a framework designed to address the critical challenges of sustainability in aquaculture. By integrating biotechnology in monosex prawn breeding, sustainable feed innovation, and scalable farming practices, the model offers a holistic approach to creating a circular protein economy. This article explores how the model leverages monosex freshwater prawn farming with sustainable aquafeed and operationalises this vision through a farming program called MUGA, aimed at empowering the farmer. Together, the CRIPE model and MUGA program redefine aquaculture's role in global food security and carbon footprint reduction.

Credit: GK Aqua

The giant freshwater prawn *(Macrobrachium rosenbergii),* locally called *udang galah* in Malaysia, is the largest species from the Palaemonid family, with male prawn being able to attain a weight of 200 g and 32 cm in length (Banu & Christianus, 2016). The species is also widely known as the Malaysian giant freshwater prawn as it was first successfully cultured in a brackish environment at the Marine Fisheries Research Institute, Penang (Malaysia), in 1961 by Shao-Wen Ling, a researcher from the Food and Agriculture Organization of the United Nations (FAO). Four years later, in 1965, Takuji Fujimura conducted commercial research in Hawaii using broodstock from Malaysia. These two researchers have been recognised as the "fathers" of giant freshwater prawn farming due to their significant contributions.

Freshwater prawn has been cultured extensively throughout the world with the global production in recent years recorded at 313 756 tonnes and valued at over USD 2.45 billion (FAO, 2023). China is the main producer of giant freshwater prawns, accounting for more than 50% of the global output, followed by Bangladesh, Thailand, Myanmar and India.

Prawn aquaculture production in Malaysia has steadily declined from 752 tonnes in 2001 to 213 tonnes in 2018. This massive reduction could potentially be due to several factors including environmental challenges, disease outbreaks, economic constraints, resource and management issues, and policy and regulatory gaps.

Within the realm of commercial aquaculture, the Department of Fisheries, Malaysia (DOF) has prioritised giant freshwater prawns as a key table food and export commodity. In order to improve seed and juvenile output, the Department has undertaken several initiatives, including the establishment of hatcheries in 1984, but these ultimately did not support commercial success.

Efforts together with the private sector were more successful; by 2013, 23 hatcheries had been established, of which four belonged to the Government. As of 2022, Malaysia's freshwater prawn hatchery landscape comprised 3–4 large-scale facilities, supplemented by numerous small-scale backyard and government-operated hatcheries. However, as seed production predominantly relies on wild broodstock whose populations have been steadily dwindling, the hatcheries have increasingly turned to broodstock sourced from grow-out ponds. About 80% of the brood prawns used by Malaysian hatcheries comes from the wild, with the remaining portion consisting of the largest and healthiest berried females selected from grow-out ponds. Poor quality broodstock can result in inbreeding, leading to low quality seed, which becomes a key obstacle to the growth of this industry.

Monosex breeding enhances survival rates

Conventional breeding practice of freshwater prawn in Malaysia involves the production of both male and female seeds. However, natural production typically results in 70% females and only 30% males, with males growing to be three times larger than females over the same rearing period. After 4–6 months into culture, the female prawns reach a plateau and pause from growing further since more energy needs to be utilised for the development of their reproductive system. There are major drawbacks associated with this mixed culture approach, including poor survival rate, low final harvest volume, higher cannibalism and difficulty in the

harvesting process due to the large variation of prawn sizes. Thus, it is plausible that separating male and female prawns for monosex culture could enhance survival rates and lead to more homogenous harvesting.

Monosex culture can be manually performed by segregating male and female prawns based on identifying gonopores through external morphology. However, this method is labour-intensive and can cause significant stress to the prawns. To address these challenges, genetic manipulation techniques such as RNA interference technology, are employed. Malaysian biotechnology company GK Aqua, established in 2016, has pioneered sustainable farming of monosex giant freshwater prawn with the production of consistently high quality all-male monosex prawn seeds, in line with the company's goal of contributing to Malaysia's food security while boosting aquaculture profitability.

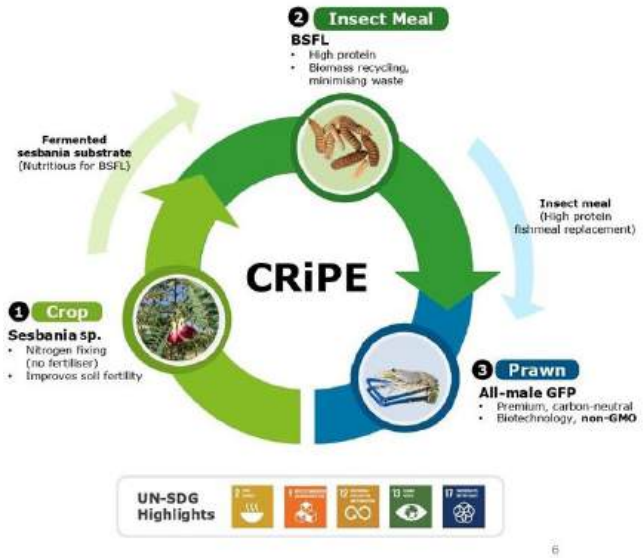
RNA interference (RNAi) is a biological process where small RNA molecules inhibit the expression of specific genes by degrading messenger RNA (mRNA) or blocking its translation. This process is a natural mechanism for regulating gene expression in cells and has been harnessed as a powerful tool in research and biotechnology. Through the administration of Mr-IAG RNAi, the male post-larvae develop into neo-female prawn that, although still carrying the male chromosome (ZZ), grow into female prawn phenotypically; they can then be included in the natural mating process with male broodstock to produce all-male post-larvae. This technique has been validated by the Malaysian Biosecurity Department (Approved in March, 2018; Ref No: JBK 100-2/1) as a process which produces non-genetically modified (GMO) or living modified organisms (LMO). Through the application of biotechnological methods, the quality of the all-male stock is further enhanced using selective breeding techniques. To support this initiative, GK Aqua established the Nucleus Breeding Centre (NBC) for giant freshwater prawns in an area near the town of Bukit Pelanduk (GPS: 2°39'25" N, 101°44'56" E) as part of its commitment to achieving the nation's goals.

The primary responsibilities of the NBC include conducting selective breeding for giant freshwater prawns and producing broodstock seed to support the multiplication efforts of accredited local and international institutions, hatcheries, or farmers, including those operated by GK Aqua. The monosex prawn breeding methodology, focused on sex marker validation, has been submitted for patent application (Patent Application No: PI2022006870) and Patent Cooperation Treaty (PCT) registration (International Application No: PCT/MY2024/050007). Beyond commercialisation, GK Aqua conducts continuous research and development to ensure the sustainability and excellence of cultivated species. Key initiatives include nutrigenetic advancements and the production of specific pathogen-free prawns, all aimed at delivering superior-quality prawns.

The carbon-resilient insular protein economy (CRIPE)

Global initiatives to produce sustainable feeds are designed to substitute finite resources which are used in animal husbandry, including aquaculture and poultry. Furthermore, as feeds take up 60 to 70% of the cost of production, nutrient efficacy and cost-effectiveness are two major factors to consider in aquaculture.

Figure 1. Carbon Resilient Insular Protein Economy (CRIPE)



Sento Biotech, a subsidiary of GK Aqua, has focused its research on developing diets made entirely from plant-based and insect-based ingredients. The increasingly higher costs involved, and limited availability of land resources for agricultural production have caused a shift in the paradigm from fish-based to plant-based ingredients and insect meal as a capable replacement.

Black soldier fly (BSF), scientifically known as *Hermetia illucens,* is a wasp-like insect from the family Stratiomyidae which is known to be an excellent bio-converter with the capability to transform any kind of organic waste into a useful source of nutrients. The larvae of the black soldier fly (BSFL) can convert over 50% of dry organic matter into high-quality feed ingredients. Its use offers numerous benefits, including reducing harmful bacteria during decomposition; providing natural antibiotics that act as growth promoters; eliminating unpleasant odours from waste materials; and modifying the microflora of organic matter. Studies have shown that insect meal can replace 25% to 75% of feed protein for aquaculture species.

Although the BSFL industry is rapidly growing and shows significant promise worldwide, challenges remain. These include a high lipid content (exceeding 25%); the retention of heavy metals such as mercury, chromium, and selenium; and food safety concerns arising from the use of agricultural and domestic wastes in the process, all of which hinder the optimal utilisation of this valuable feed ingredient in animal nutrition.

At GK Aqua's research facility, an underutilized crop called Sesbania *(Sesbania grandiflora)* was used as a sustainable and renewable substrate for cultivating black soldier fly (BSF) larvae, efficiently converting biomass into high-quality protein while reducing reliance on marine-derived feed ingredients. Several feeding trials were conducted to determine the optimal percentage of black soldier fly (BSF) insect meal, derived from a Sesbania substrate and marketed as Sento insect meal, in enhancing the growth and fecundity of giant freshwater prawns. The commercial pellets were used as a negative control, while pellets formulated entirely from fishmeal served as a positive control. After three months, post-harvest

analysis revealed that up to 75% of Sento insect meal could replace marine protein without compromising prawn survival or growth. The insect meal also contains a high protein level (55%); lower lipid content (less than 10%); and significant amounts of essential amino acids (EAAs); while the presence of heavy metals remains below the detection level.

Additional trials focusing on prawn fecundity demonstrated significant weight gain and a 56% increase in mating success among prawns fed with Sento-formulated pellets compared to those on a commercial diet. The integration of Sesbania, Sento insect meal and monosex prawn breeding exemplifies a transformative approach in building a carbon-resilient insular protein economy (CRIPE) in aquaculture. The process not only minimises greenhouse gas emissions and waste but also enhances resource efficiency by upcycling agricultural residues and reducing feed-associated environmental impacts.

The use of Sesbania and the method of preparing thereof has been submitted for patent application, PI2023001409 and subsequently filed under the Patent Cooperation Treaty (PCT) (International application no: PCT/MY2024/050026).

The Malaysian *Udang Galah* Aquapreneur (MUGA) program

GK Aqua and Sento Biotech are implementing the Malaysian *Udang Galah* Aquapreneur (MUGA) program within the framework of the CRIPE project. This initiative focuses on empowering Malaysians belonging to the "B40" economic strata, i.e. the bottom 40% of household income earners. Currently, ten participants have embarked on this transformative aquapreneurial journey with financial support from Agrobank Malaysia. The program provides participants with high-quality prawn post-larvae, sustainable feed, and cutting-edge technology transfers, equipping them with the tools needed to enhance farm management and maximise production efficiency.

The MUGA program goes beyond mere technical assistance by fostering opportunities for aquaculture entrepreneurship, enabling participants to generate sustainable incomes and elevating their living standards. The program integrates comprehensive training provided by GK Aqua on environmentally sustainable aquaculture practices, emphasising ecosystem conservation, effective water quality management, and biodiversity preservation. This ensures that farming operations are conducted in harmony with nature, mitigating environmental impacts while optimising resource use.

Furthermore, the program adopts a holistic approach to community development by combining innovative aquaculture practices with financial literacy and business management training. Participants are empowered to scale their operations and contribute to a thriving circular economy, aligning with Malaysia's broader vision of sustainable economic growth. By bridging advanced biotechnology with grassroots implementation, the collaborative efforts of GK Aqua and Sento Biotech through the CRIPE model and MUGA program showcase a scalable model for achieving social, economic, and environmental resilience in aquaculture.

Sesbania grandiflora, a fast-growing native of tropical countries, is a sparsely-branched soft wooded tree containing nutraceutical properties. The plant plays a significant role in supporting a carbon-resilient protein economy, being highly effective at sequestering carbon dioxide from the atmosphere during its rapid growth cycle. Sesbania's ability to fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria in its root nodules further enhances its role in soil health and carbon sequestration. This process, known as biological carbon capture, directly contributes to reducing greenhouse gas concentrations, making it a valuable asset in mitigating climate change impacts.

By improving soil organic matter and fertility, Sesbania not only supports sustainable agriculture but also reduces the need for synthetic fertilisers which are energy-intensive to produce and which release significant carbon emissions.

Giva Kuppusamy *is the Founder & CEO of GK Aqua and Sento Biotech, driving cutting-edge innovations in aquaculture biotechnology. With expertise in sustainable aquaculture and biotechnology, he pioneered the development of all-male Malaysian giant freshwater prawns, a breakthrough with significant economic impact. His contributions have earned him multiple accolades, including the National Aquaculture Award (MAHA 2022), Best ASEAN Startup (MBAN Summit 2022), and EY Entrepreneur of the Year (Tech Category 2023). As a Commonwealth Scholar with a Master's in Sustainable Aquaculture from the University of St. Andrews, Scotland, he actively collaborates with global institutions and advises on national biotech policies. His leadership in next-generation sequencing, sustainable feed development, and disease management is shaping the future of aquaculture.*

Dr M Janaranjani *is an aquaculturist and molecular biologist with extensive experience in nutritional genomics, aquaculture biotechnology, and sustainable feed development. She holds a PhD in Molecular Biology from Universiti Sains Malaysia and has contributed significantly to advancing prawn genetics, alternative protein sources, and disease screening methodologies in aquaculture. As a Senior R&D Manager at GK Aqua Sdn Bhd, she leads multiple research projects, oversees collaborations with academic and industry partners, and has successfully secured research grants and patented innovations. Her expertise in molecular cloning, bioinformatics, and aquaculture sustainability is reflected in numerous high-impact scientific publications. She remains dedicated to driving innovation in aquaculture for a more sustainable and resilient seafood industry.*