Commercializing Agro-Based R&D in Malaysia: A Case Study of "Break and Protect 2", a Marine Leech Trap

Wan Norhana Md Noordin*
Innovation, Promotion and Commercialization Centre
Fisheries Research Institute
11960, Batu Maung, Penang
Malaysia

Liyana Ramli
Innovation, Promotion and Commercialization Centre
Fisheries Research Institute
11960, Batu Maung, Penang
Malaysia

Kua Beng Chu
Fisheries Research Institute
11960, Batu Maung, Penang
Malaysia

Received 06 January 2025 Revised 17 March 2025 Accepted 20 June 2025

ABSTRACT
Commercialization of R&D products by Government Research Institutions (GRI) in Malaysia is still modest, particularly in agro-based R&D. Furthermore, information sharing of the commercialization experience by GRIs or academia is also very scarce and provides little practical guidance. Hence, this article is prepared to describe the Fisheries Research Institute, Department of Fisheries' experience in commercializing our first aquaculture R&D technology, i.e., a device to combat marine leech (an ectoparasite) infestations in marine fish culture, named 'Break and Protect 2' (BP2). The marine leech poses a significant challenge to optimal aquaculture production in Southeast Asian countries. BP2 has been proven to decrease marine leech infestation levels and safeguard the marine environment through minimizing chemical use, offering an eco-friendly solution crucial for sustainable aquaculture. In 2020, this technology was licensed to a local aquaculture products company and available in the market in 2022. Critical factors that assisted in the commercialization of BP2 were good partnership with licensee and users, significant selling points, government support and ownership of intellectual property rights. The issues that hindered the commercialization and way forward are also highlighted.

Keywords: *Government Research Institutions, Aquaculture, Commercialization, Licensing, Leech Trap*

Paper type: Research paper

1. Introduction

In simple terms, commercialization refers to activities required to introduce an innovation from the Research and Development (R&D) infrastructure to the market (Kelm et al., 1995; Narayanan et al., 2000). It is a rigorous and complex exercise that requires policy direction, funding, business plan and human resources capability throughout the course. Although intricate, the outcome of technology commercialization enhances trade, economic growth and welfare improvement at the national level (Jjagwe

**Corresponding author: Dr Wan Norhana Md Noordin, Email: norhana@dof.gov.my*

et al., 2024).

In Malaysia, efforts towards commercialization were initiated in the 6th Malaysia Plan (MP) (1991-1995), and extended to the 7th (1996-2000), 8th (2001-2005) and 9th (2006-2010) MP (Chandran, 2010). In the 8th MP, a total of MYR 836.9 million were allocated for R&D, followed by MYR 3.101 billion and MYR 741 million in the 9th MP and 10th MP (2011-2015) (Ali et al., 2017) as well as pre-commercialization funds (e.g., Technofund, Innofund, Technology Development (TED) Fund, The Bridging Fund). These funds helped to develop new or improve existing products or technologies in specific areas to establish new businesses or create wealth creation. Besides funding, emphasis on commercialization was also reflected in the introduction of policy and initiatives, namely the National Intellectual Property Policy (2007), the Intellectual Property Commercialization Policy for Research and Development Projects Funded by the Government of Malaysia (2009), the establishment of science and technology parks like the Malaysian Research Accelerator for Technology & Innovation (MRANTI) to help incubate ideas, technology and business. All these efforts were designed to encourage local inventions, works and designs that will create jobs and add to the country's economic growth to accelerate the rate of commercialization.

Malaysia has demonstrated a steady rise in the number of IP filings. Between January 2013 and December 31, 2018, a total of 282,825 IP applications were recorded. During the same period, MyIPO approved a total of 215,036 IP registrations (Anon., 2019). Despite high numbers of IPRs, the commercialization rate of publicly funded projects was minimal. According to a report by the Ministry of Science, Technology and Innovation (MOSTI) in 2019, commercialization of R&D products was between 8-9% during the 11th MP, which was slightly higher than the 10th MP (5-6%). Out of 7,899 IPS filed in 2017, the return of investment from the R&D projects was only RM1.60 million (USD 0.36 million) (MASTIC, 2020). This could indicate weak local innovative capabilities (Chandran et al., 2009; Chandran & Wong, 2011; Ismail et al., 2015). Apart from that, Ali et al. (2017) stated that industry players were not keen on Malaysian R&D products because the products were prototype versions that could not be sold in the market and they were not willing to invest to upgrading the products from lab scale to the up-scaling level.

Commercialization is a major obstacle to researchers from government research institutions (GRIs). In general, universities have more R&D commercialization paths (from spin-offs, joint ventures to technology transfer via licensing) compared to GRIs due to their statutory constraints (Baharudin & Mohd Farid, 2020; Hailu, 2024; Martínez-Ardila et al., 2023). In addition to statutory restrictions, the lack of know-how and clear mechanisms also hinder GRIs in accomplishing commercialization. However, these has not stalled the Fisheries Research Institute (FRI), Department of Fisheries (DOF) in embarking on the commercialization journey. This article presents FRI's experience in commercializing a marine leech trap, called Break and Protect 2 (BP2). It is hoped that researchers from other GRIs could acquire some insights into the commercialization process that could be accomplished within their limits.

2. Marine leech problem in aquaculture

Aquaculture is an important agriculture subsector with great potential for food security, poverty mitigation, prospective trading, and other benefits that match the United Nations Sustainable Development Goals (Food and Agriculture Organization (FAO) 2022). The significant progress in aquaculture has been largely attributed to the intensification of fish production and aquaculture transformation. One of the aquaculture transformation themes is biosecurity and disease control (FAO, 2022).

Fish are known to be affected by many kinds of parasites and in some cases may lead to mortality. Parasite infestation and resulting secondary infections were acknowledged as the main contributors associated with losses in farmed fish (Kotob et al., 2017). For instance, an ectoparasite (which affects the fish externally, includes the skin, eyes, fins, and gills) such as the marine leech (*Pterobdella arugamensis*, previously named *Zeynicobdella arugamensis*), is an essential threat to the aquaculture industry. Prevalence of *P. arugamensis* in various cultured fish especially groupers was well documented around the Indo-West Pacific region, encompassing Brunei Darussalam (Azmey et al., 2020; Wafi et al., 2023), China (Wang et al. (2018), India (Sanjeeva et al., 1977), Indonesia (Murwantoko et al., 2017; Mahardika et al., 2018, Gunati et al., 2020), Iran (Polgar et al., 2009), Japan (Nagasawa & Uyeno, 2009), Peninsular Malaysia (Kua et al., 2010; Ravi & Yahya 2017), Philippines (Cruz-Lacierda et al., 2000), Singapore (De Silva & Fernado), South Africa (Hayes et al., 2006) and Sri Lanka De Silva, 1963).

Fish that are infested with marine leeches on their skin will usually rub their body against surrounding objects, creating injuries and ulcerations on the skin. Although pathogenicity is low initially, in severe infestation cases, the vast number of leeches that latch to the fish to suck blood may cause chronic anemia, skin lesions, wounds, decreases decrease in appetite, tamper growth and finally mortality ((Cruz-Lacierda et al., 2000; Noga 2010, Suyanti, 2021). The infestation could instigate secondary infections as marine leeches have been proven to be a vector for fish pathogens such as *Vibrio alginolyticus* (Kua, 2008; Kua et al., 2009). Besides that, leeches may also transmit microbes and hemoparasites (Noga 2000). Marine leeches were also reported to have the ability to transmit the hemogregarine and trypanosomes simultaneously between fish (Hayes et al. 2006). According to Kua & Leaw (2024), the extent of injury to the host largely depends on the number of attached leeches.

The cost of treatments, prevention, and even reduced fish growth due to loss of fish appetite because of treatments or the parasites can also be substantial and put a burden on farmers (Mustafa et al., 2001). In Malaysia, leech infestations in Penang caused losses of RM 6 million in 2014 and RM 1.1 million in 2016. The magnitude of losses caused by marine leeches has resulted in this parasite being placed on the Malaysian notifiable disease list under the DOF, Malaysia. Until the year 2014, a total of 14 marine fish species including hybrid grouper (*Epinephelus fuscoguttatus* x *E. lanceolatus*; *E. fuscoguttatus* x *E. coioides*; *E. lanceolatus x E. coioides*), tiger grouper (*E. fuscoguttatus*); giant grouper (*E. lanceolatus*); green grouper (*E. coioides*); mangrove red snapper (*Lutjanus argentimaculatus*); crimson snapper (*L. erytopterus*); golden snapper *(L. johnii*); Asian seabass (*Lates calcarifer*); cobia (*Rachycentron canadum*) and golden pompano (*Trachinotus blochi*) were identified to be at risk of being infected by marine leeches, with a prevalence between 40%–100% (Kua, 2020). If preventive measures are not implemented in a timely manner, then infestations can spread and result in mortality, leading to greater economic loss to the farmer.

Traditional treatment for leech infestation involves removing the leeches manually by hand, brush, or towel, which is stressful to the fish and operator. Other treatments include using chemicals such as formalin, acriflavine, or antibiotics; However, this is not environmentally friendly. A fresh water bath is also an option, but not practical or guaranteed (Kua, 2019). Marine leech elimination using tropical plant-based extracts was also investigated (Wan Norhana et al., 2021). Although four plant extracts (*Melastoma malabathricum, Piper betle, Tetracera indica,* and *Etlingera coccinea*) were found to exhibit anti leech activity, practical application to overcome infestation at the cage culture sites were not straightforward.

All these shortcomings have driven BP2 innovation, which is based on physical mitigation methods by providing a substrate for adult marine leeches to lay their cocoons in fish cages. The device also attracts the fish to hide inside them, thus mobilizing the leeches nearer to the trap. The device lures the leeches to detach from the host and lay their cocoons on its surface. After a few days in cages, BP2 is removed, along with both adult leeches and their cocoons, and cleaned properly and reused after that. Continuous removal and deployment of BP2 over a fixed period aids in reducing marine leech prevalence. Trials conducted at fish culture sites demonstrated that the use of the device resulted in the presence of adult marine leeches and an uncountable number of cocoons. The prevalence of marine leeches in infected fish in cages equipped with the device was observed to be 50% lower compared to those in cages without the device. A one-way ANOVA showed a significant difference ($p < 0.05$) in the prevalence of leech infection between the two groups (Kua, 2020). Continuous use of BP2 in marine fish cages successfully reduced the prevalence of marine leech infestation from 80%-100% to just 20%-28% (unpublished data).

3. Innovation of Break and Protect 2 (BP2)

BP2 is a device for trapping marine leech and reducing the number of leech infestations from caged-cultured marine fish. It is novel in the way that it could avoid leech infestation on fish by applying leeches' life cycle information and fish's natural behaviour. The device not only removed adult leeches, but also cocoons (eggs) from fish cages without using any chemicals. As marine leeches are ever present in the sea, it is important to continue applying BP2 in the cages every five days to ensure that the leeches' lifecycle is disrupted, and the fish are protected. In addition, BP2 is easy to apply and reduces handling stress on fish. The primary goals of BP2 are to minimize unsold fish caused by injuries, prevent re-infestation of the marine leech parasite, and decrease the reliance on chemical treatments for leech control.

4. R&D activities, technology platform and prototype stages

The study on the completion of the marine leech life cycle was initiated during the 9th MP. Development of BP 2 was initiated in the 10th MP through MOSTI under Science Fund grants worth RM 156,000 to carry out a project entitled "Marine leech, *Z. arugamensis* infestation in marine farm fish: Occurrence, Pathogenicity & Control Measures" (Project No: 04-03-06-SF0029) from 2013 to 2015. This project was led by Dr Kua Beng Chu and Ms Nur Ashikin Arbi from the Parasitology Laboratory, National Fish Health Research Center, FRI, DOF. The device was evaluated at the field cages in Bukti Tambun, Penang and demonstrated to successfully trap marine leech and reduce the prevalence from 70% to 20% (Kua, 2015).

The initial prototype was filed as a patent in 2012 with the title "Controlling Leech Infestation During Fish Culture" (PI 2012000290) and referred as Break and Protect (BP), which translates the concept of innovation, i.e., to break the life cycles of the leech and protect the fish from cannibalism. After eight years, the patent was granted in August 2018, with certificate no MY-167115-A. However, the status of the patent was lapsed because of miscommunication with a previous FRI's IP agent that had ceased operation. Later in the 11th MP, the original BP was improvised, named BP2 and filed as a patent in 2017 with the new title "Leech Remover" (PI No. 2017703059) (Liyana & Wan Norhana, 2024). This application was granted on 12 September 2024 with certificate number MY-204788-A. To make this innovation easily recognized and associated with FRI, DOF, a trademark for BP2 was filed in 2024 (Figure 1).

Figure 1: *Break and Protect 2 trademark*

5. The selling attributes of BP2

Potential for international market

As mentioned earlier, marine leech infestation does not only occur in Malaysia but also in neighbouring South East Asian and other tropical countries. These are the main favourable aspects of BP2, which are for the domestic and export market.

A simple device

BP2 is a very simple device to manufacture using local, readily available and inexpensive raw materials. It is easy to handle, does not require large storage space, has no specific storage environment and is easy to transport. Designed with single operator and allows individuals of all experience levels to operate it effortlessly. The device offers a quick setup process and saving time, thereby ensuring accessibility for everyone. The device could be produced in an ordinary plant without having to obtain good manufacturing practices (GMP) requirements. Unlike fish vaccines, probiotics or electrical appliances, the application of this device to the fish cages does not require certification or clearance from a relevant authority in Malaysia, such as the Department of Veterinary Science (DVS) or Department of Environment Malaysia (DOE), or Standard and Industrial Research Institute of Malaysia (SIRIM).

Green technology

Application of BP2 replaced the use of harmful antimicrobial in aquaculture. Thus, BP2 could be categorized as a green technology product which promotes economic sustainability and protects the environment. This could be a good marketing strategy for BP2, especially in the international market, where there is stronger awareness of environmental issues and sustainability value. Its effectiveness and commitment to sustainability were recognized when BP2 received an award from the Commonwealth in 2021.

User-friendly and cost-effective

BP2 is user-friendly. It only requires one worker to operate BP2 compared to conventional methods that require a lot of labour to remove the leeches manually. This does not only cause stress on the fish but also on the operator. The less expensive and more effective technology products will generate more commercial value.

Others

BP2 development and trials were reported in prestige and high-impact journals. Apart from that, the BP2 inventor is also recognized nationally, regionally and internationally for her work in fish health management, particularly with parasites. Being 100% IP owned by the DOF makes the BP2 commercialization process less hassle as it does not involve other IP owners from different institutions.

Apart from that, BP2 has earned several awards at the national and international level (Anon., 2022). In 2018, BP2 received a gold medal at the National Innovation & Invention Competition Exhibition 2018 (iCompEx'18) and was 2nd Runner-up in the Agriculture, Environment and Renewable Energy Category. In addition, BP2 also won a silver medal in the 4th International Innovation, Design & Articulation 2018 (i-IDeA 2018). The highest recognition was accomplished through the Commonwealth Secretary-General's Innovation for Sustainable Development Award (Commonwealth Innovation Awards 2021-Government Category) in 2021 with £3000 of prize money (Anon., 2021).

6. Scaling up and commercialization stages of BP2

In 2019, FRI was approached by a local aquaculture trading company dealing in reproductive and health products for fish and shrimp to commercialize BP2. After several discussions, both parties agreed to proceed with a commercialization path via technology transfer. This path was the preferred option for other GRIs in Malaysia as described by Baharudin & Mohd Farid (2020). This path enables GRIs to focus on executing the relevant R&D and perfecting the technology and later choose a capable industrial player to execute commercialization and, in exchange, receive licensing fees and royalties. Since this is the first experience for FRI, key obstacles faced at this stage included unclear policy and procedures, insufficient technology and entrepreneurial skills among the personnel involved.

Despite the shortcomings, the FRI commercialization journey was advanced. After getting approval and endorsement by the top management, the licensing agreement was drafted and signed on 27th May 2020. The agreement was valid for 5 years. The licensee was subjected to a one-off processing and licensing fee and minimal yearly royalty payment. The fees were deposited in the Government Revenue Fund. Although FRI owns a trust account, it is only for depositing funds to carry out R&D from private entities and individuals and not from commercialization activities. However, in 2021, the scope of the FRI trust fund has been amended to include payment from commercialization.

It took a while for the company to find an appropriate production facility and perfectly fabricate BP2 suitable to its function. The company received a National Technology and Innovation Sandbox (NTIS) grant worth around MYR 215,000 from the MTDC for 2022-2023. Only in November 2022 was BP2 officially launched and ready to be traded. A focused, tailored technology transfer was implemented through social networking, participation in various events, on-site demonstration and user training. BP2 was evaluated in several fish culture areas throughout Peninsular Malaysia, including Sabah, Kelantan, Penang, Terengganu, Sarawak, Perak, Selangor, Johor and Brunei Darussalam (Tan et al., 2022; Kua et al., 2024). Feedback from users in Brunei, for example, showed a significant reduction in leech prevalence under captivity, while Sabah farmers promisingly removed 16,190 adult leeches and over 601,000 cocoons within 15 days of BP2 application (Kua et al., 2024). These outcomes strengthen the initial findings that BP2 effectively reduces marine leech infestations and provides an eco- and user-friendly approach to sustainable aquaculture. Photos of the field trials and evaluation were mostly updated on the FRI Facebook as promotion and records.

The company not only provides strong technical support for the products but, together with the inventor, actively shares and disseminates technical know-how and assists the customers. The strong partnership and good communication between FRI, DOF and the company has helped to create awareness of BP2 among the farmers and helped in the commercialization process as suggested by Mustapha et al. (2021).

7. Issues and Challenges

General commercialization challenges were similar to those reported by Baharudin & Mohd Farid (2019) and Baharudin & Mohd Farid (2020). Specific challenges include low demand for BP2 among fish farmers. Farmers in Malaysia often struggle with limited capital. Although currently priced at around MYR 250/unit (USD 56.00, conversion ratio 1 MYR = 0.224502 USD 1 USD = 4.45429 MYR), it is still considered an additional burden to the existing high operating costs. Commercialization of agricultural R&D products is very important, especially to address food security. The less expensive and more effective technology products will generate more commercial value.

In terms of protection, the BP2 design is simple and easy to copy. Furthermore, it is only registered in Malaysia, thus the IP rights are only valid in Malaysia. Therefore, it may be defenceless for DOF to trade BP2 internationally. However, in order for users to attain the optimum benefits from a BP2 application, certain procedures need to be followed, and require tailored technical advice from FRI. This requirement could perhaps secure BP2 trading.

8. Way Forward

It is well understood that successful R&D commercialization is an uphill battle. Nevertheless, since this is our first milestone in commercialization, our next mission is to get BP2 to the right place (distribution channels) with the right promotion (creating awareness and branding). Having a clear understanding of the application of BP2 is not enough to make it successful in the market. Continuation with large-scale on-farm evaluation and credible data sets are needed to demonstrate the benefits and advantages of BP2 deployment. Farmers listen to other farmers. So, conclusive data from large-scale field trials in certain areas by respective farmers are influential in advancing new products from awareness to trial use and on toward adoption. In short, the pathway to successful commercialization includes a go-to-market and technology transfer program with a clear, concise and credible testimonial supported by scientific facts.

There is a saying that says “update or die". Similarly, with BP2, the inventor should continue the R&D to provide other supporting information such as the shelf life of BP2 and the recommendation on the number of BP2 sets to be used for certain cage perimeter in order to get optimal results in reducing leech infestation. In addition, the manufacturer’s instruction leaflet with all pertinent details including the application of BP2 on site, how to dispose of the attached adult leeches and cocoons, how to clean and store BP2 could be handy and useful. Last but not least, aggressive promotion of BP2 on all kinds of platforms and networking should be encouraged.

9. Conclusion

The commercialization path through licensing approach was the best option for BP2 as it reduces the risk of falling into the valley of death in the innovation diffusion curve. By having a collaboration with a local aquaculture products company with relevant experience and business infrastructure already in place, assisted BP2's introduction to relevant industrial players. Although the process was rigorous and rocky, it also serves as a learning process for both licensor and licensee.

Despite the limitations, technology commercialization is still achievable at the GRIs. It is hoped that the experience and sharing of information could empower our researchers to pursue their commercialization goals. One thing that we learned for sure, is being obsessed with quick wins does not complement the conversation about innovation. Although the monetary gain from BP2 commercialization is not very lucrative at present, the intangible impact in the form of substantial economic benefits to the farmers, the environment and aquaculture industries in securing food for the countries was worth doing.

This case study demonstrates the successful commercialization of an innovative aquaculture technology to address marine leech infestations. Our journey illustrates that with the right strategy, institutional backing, and industry collaboration, agro-based R&D can achieve real-world impact. We hope this experience encourages other GRI to pursue commercialization for societal and economic benefit

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

This paper does not receive financial assistance from governmental, private, or non-profit organizations. We would like to thank Ms Sugania Vijayan and Ms Erin Tan from 3 Little Fish Sdn. Bhd. for sharing pertinent information regarding the BP2 development and transfer of technology activities.

References

Ali, R., Leman, A., Mohamed Sunar, N., & Ahmad, A. (2017). Issues Related to Low Commercialisation Rates of the University’s Research and Development (R&D) Products: Industrial Perspective. *Advanced Science Letters*, 23, 10616-10620.

Anon., (2019). Keynote Speech: YB Datuk Seri Saifuddin Nasution Ismail Minister of Domestic Trade and Consumers Affairs First IP & Innovation Researchers of Asia Conference. Universiti Islam Antarabangsa. Available at: https://www.kpdn.gov.my/en/media-kpdnhep/teks-ucapan/menteri/2019-menteri?download=190:01022019-first-ip-iium-2

Anon., (2021). Commonwealth Innovation Awards 2021 Winners. Available at: https://thecommonwealth.org/innovation/awards-2021

Anon., (2022). R&D Innovation on Fish Health Management and Disease Control. Available at: https://www.fhs-afs.net/pdf/pub/3.Innovation-Booklet-DAA11.pdf

Azmey, S., Taruna, M., Taha, H., & Arai, T. (2020). Prevalence and infestation intensity of a piscicolid leech, *Zeylanicobdella arugamensis* on cultured hybrid grouper in Brunei Darussalam. *Veterinary Parasitology: Regional Studies and Reports,* 20, 100398. https://doi.org/10.1016/j.vprsr.2020.100398

Baharudin, K., & Mohd Farid, S. (2019). A case study Analysis of Typhidot: An Example of Market-Oriented R&D Commercialization in Malaysia. *International Journal of Financial Research,* 10(5), 75-81. https://doi.org/10.5430/ijfr.v10n5p75

Baharudin, K. & Mohd Farid, S. (2020). Licensing Approach to R&D Commercialization among Government Research Institutes in Malaysia – Lessons from Selected Cases. *TEST Engineering & Management* 82, 4264-4266. http://www.testmagzine.biz/index.php/testmagzine/article/view/1507

Chandran, V. G. R., (2010). R&D Commercialization Challenges for Developing Countries: The Case of Malaysia. *Tech Monitor*, 25-30. https://idl-bnc-idrc.dspacedirect.org/bitstreams/41074b4d-3420-442f-a14d-67bc8e5ee7a1/download

Chandran, V. G. R., Rasiah, R., & Wad, P. (2009). Malaysian Manufacturing Systems of Innovation and Internationalization of R &D. *CBDS Working Paper Series Working Paper* Nr. 11, 2009. https://research-api.cbs.dk/ws/portalfiles/portal/58952872/MSI_and_internationalization_of_R_D.pdf

Chandran, V. G. R. & Wong, C. Y. (2011), “Patenting activities by developing countries: The case of Malaysia”, *World Patent Information*, Vol. 33, 51-57. https://doi.org/10.1016/j.wpi.2010.01.001

Cruz-Lacierda, E. R., Toledo, J. D., Tan-Fermin, J. D., & Burreson, E. M. (2000). Marine leech (*Zeylanicobdella arugamensis*) infestation in cultured orange-spotted grouper, *Epinephelus coioides*. *Aquaculture*, 185(3-4), 191-196. http://dx.doi.org/10.1016/S0044-8486(99)00356-7

De Silva, P. H. D. H., & Fernando, C. H. (1965). Three marine leeches (Piscicolidae, Hirudinea) from the Malay peninsula. *Spolia Zeylan*., 30, 227–232.

De Silva, P. H. D. H. (1963). *Zeylanicobdella arugamensis* gen. nov. and sp. nov. from Arugam Kalapu, Eastern Province, Ceylon. *Spolia Zeylan*., 30, 47–53.

FAO, (2022). The State of World Fisheries and Aquaculture. Intensifying and expanding sustainable aquaculture production. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/9df19f53-b931-4d04-acd3-58a71c6b1a5b/content/sofia/2022/expanding-sustainable-aquaculture-production.html

Gunanti, M., Umi Hafid, L., Fungky, P. Pratama, Dicky R., Sri Subekti, Putri D. Wulansari, Muhamad Amin, (2020). Prevalence, intensity and histopathology of *Zeylanicobdella arugamensis* infestation on groupers reared on different aquaculture systems. *Journal of Fish Diseases*, 43(10), 1133-1143. https://doi.org/10.1111/jfd.13219

Hailu, A. T. (2024). The role of university–industry linkages in promoting technology transfer: implementation of triple helix model relations. *Journal of Innovation and Entrepreneurship*, 13(1), 25. https://innovation-entrepreneurship.springeropen.com/articles/10.1186/s13731-024-00370-y

Hayes, P. M., Smit, N. J., Seddon, A. M., Wertheim, D. F. & Davies, A. J. (2006). A new fish haemogregarine from South Africa and its suspected dual transmission with trypanosomes by a marine leech. *Folia Parasitology*, 53,241-248. https://dx.doi.org/10.14411/fp.2006.031

Ismail, N., Nor, M. J., & Sidek, S. (2015). A framework for a successful research products commercialisation: A case of Malaysian academic researchers. *Procedia - Social and Behavioral Sciences*,195, 283 - 292. https://doi.org/10.1016/j.sbspro.2015.06.163

Jjagwe, R., Kirabira, J. B., Mukasa, N., & Amanya, L. (2024). The drivers and barriers influencing the commercialization of innovations at research and innovation institutions in Uganda: a systemic, infrastructural, and financial approach. *Journal of Innovation and Entrepreneurship*, 13(1), 78. https://doi.org/10.1186/s13731-024-00435-y

Kelm, K. M., Narayanan, V. K. & Pinches, G. E. (1995). Shareholder value creation during R&D innovation and commercialization stages. *Academy of Management Journal*, 38, 770 - 78. https://doi.org/10.2307/256745

Kotob, M. H., Menanteau-Ledouble, S., Kumar, G., Abdelzaher, M., & El-Matbouli, M. (2017). The impact of co-infections on fish: a review. *Veterinary Research*, 47, 1-12. https://doi.10.1186/s13567-017-0432-7.

Kua, B.C. (2008). What is the risk of leech infestation in cultured marine seabass? *FRI Newsletter*, Fisheries Research Institute, Department of Fisheries Malaysia, Volume 12 (1), 22.

Kua, B. C., Burreson, E. M.& Oo, M. G. (2009). Morphology of haematophagous marine leech (*Zeylanicobdella arugamensis*) isolated from sea bass (*Lates calcarifer*). *Malaysian Fisheries Journal*, 8,17-21.

Kua, B. C., Azmi, M. A., & Hamid, N. K. A. (2010). Life cycle of the marine leech (*Zeylanicobdella arugamensis*) isolated from sea bass (*Lates calcarifer*) under laboratory conditions. *Aquaculture*, 302(3-4), 153-157. https://doi.org/10.1016/j.aquaculture.2010.02.029

Kua, B. C., Choong, F. C., & Leaw, Y. Y. (2014). Effect of salinity and temperature on marine leech, *Zeylanicobdella arugamensis* (De Silva) under laboratory onditions. *Journal of Fish Diseases*, 37(3), 201-207. https://doi.org/10.1111/jfd.12087

Kua, B. C. (2015). Break & Protect: Control measure of marine leech *Zeylanicobdella arugamensis* infecting grouper *Epinephelus* spp. in cages culture. *FRI Newsletter* 18, 24.

Kua, B. C., Muhd. Naim A. M. & Horng C. K. (2019). Reoccurrence of Marine Leech *Zeylanicobdella arugamensis*, A Marine Fish Parasite Following a Freshwater Bath. *Biomedical Journal Scientific & Technology Research*, 22(4), 16881-16884. http://dx.doi.org/10.26717/BJSTR.2019.22.003794

Kua, B. C. (2020). Technical Report: *Zeylanicobdella argumensis*, a marine leech infestation of farmed fish: occurrence, pathogenicity & control measure. ISBN:978-967-2946-05-2. 101 pg.

Kua, B. C., & Leaw, Y. Y. (2024). Pathogenicity associated with an infestation of the marine leech parasite *Pterobdella arugamensis* in farmed fish. *Diseases of Aquatic Organisms*, 158, 179-184. https://doi.org/10.3354/dao03794

Kua, B.C., Nur Ashikin, A., Syarinah, S., Sugania, V., Erin, T., & Wan Norhana M.N. (2024). Technology Transfer of Break & Protect 2(BP2): A Device for Trapping the Marine Leech *Zeylanicobdella arugamensis* in Cultured Fish. Poster presented at the Sustainable Aquaculture Summit 2024, USM, Bukit Jambul, Penang, 15 Oct 2024.

Liyana, R., & Wan Norhana, M.N. (2024). An Overview on the Intellectual Properties of the Fisheries Research Institute, Department of Fisheries, Malaysia. Malaysia *Journal of Invention and Innovation*, 3(6), 46-59. https://digit360.com.my/mjii/index.php/home/article/view/101

Mahardika, K., Mastuti, I., Sudewi, S., & Zafran, Z. (2018). Identification and life cycle of marine leech isolated from cultured hybrid grouper in the northern Bali waters of Indonesia. *Indonesian Aquaculture Journal*, 13(1), 41-49. http://dx.doi.org/10.15578/iaj.13.1.2018.41-49

Martínez-Ardila, H., Castro-Rodriguez, Á., & Camacho-Pico, J. (2023). Examining the impact of university-industry collaborations on spin-off creation: Evidence from joint patents. *Heliyon*, 9(9). https://doi.org/10.1016/j.heliyon.2023.e19533

MASTIC, (2020). Malaysian Science, Technology and Innovation (STI) Indicator Report 2020. Available at: https://mastic.mosti.gov.my/publication/malaysian-science-technology-innovation-sti-indicators-report-2020/

Murwantoko, M., Negoro, S. L. C., Isnansetyo, A., & Zafran, Z. (2017). 1811 Life Cycle of Marine Leech from Cultured "Cantik" Hybrid Grouper (*Ephinephelus* sp.) and Their Susceptibility Against Chemicals. *Aquacultura Indonesiana*, 72-76. http://dx.doi.org/10.21534/ai.v18i2.91

Mustafa. F. N., Salahuddin, N. M. S & Abu Dardak, R. (2021). Commercialization of Public Funded Agro-based Technologies to SMEs in Malaysia: The Roles of Government Research Institution and Private Firms. *FFTC Agricultural Policy Platform*. Available at: https://ap.fftc.org.tw/article/2940

Mustafa, A., Rankaduwa, W. & Campbell, P. (2001). Estimating the cost of sea lice to salmon aquaculture in eastern Canada. *Canada Veterinary Journal*, 42, 54–56. PMID: 11195524; PMCID: PMC1476418.

Nagasawa, K. & Uyeno, D. (2009). *Zeylanicobdella arugamensis* (Hirudinida, Piscicolidae), a leech infesting brackish-water fishes, new to Japan. *Biogeography*, 11, 125–130. https://ir.lib.hiroshima-u.ac.jp/30960/files/36976

Narayanan, V. K., Pinches, G. E., Kelm, K. M., & Lander, D. M. (2000) The influence of voluntarily disclosed qualitative information. *Strategic Management Journal*, 21, 707–722. https://DOI:10.1002/1097-0266(200007)21:73.0.CO;2-A

Noda E. J. (2000). Fish Disease Diagnosis and Treatment. Iowa State Press. Iowa.

Ravi, R. & Yahaya, Z. S. (2017). *Zeylanicobdella arugamensis* The Marine Leech from Cultured Crimson Snapper (Lutjanus erythropterus), Jerejak Island, Penang, Malaysia. *Asian Pacific Journal of Tropical Biomedicine* 7:473-477. https://doi.org/10.1016/j.apjtb.2017.01.018

Sanjeeva, R. P. J., Babu, S. J. & Gladstone, M. (1977). Anatomical details of two fish leeches from the Pulicat Lake, South India. *Journal of Marine Biology Association India*, 19, 35–43. https://www.mbai.org.in/uploads/manuscripts/Article%205(35-43)1642174527.pdf

Suyanti, E., Mahasri, G., & Lokapirnasari, W. P. (2021). Marine leech *Zeylanicobdella arugamensis* infestation as a predisposing factor for vibrio alginolyticus infection on the hybrid grouper "cantang" (*Epinephelus fuscoguttatus* x *Epinephelus lanceolatus*) from traditional ponds in the Kampung Kerapu Lamongan East Java Indonesia in *IOP Conference Series: Earth and Environmental Science*, 718 (1), 12-35. IOP Publishing. http://dx.doi.org/10.1088/1755-1315/718/1/012035

Tan Erin C. W., Sugania, V., Kua B. C., Muhammad Haziq, A & Ann-Jie, G. (2022). Novel Method for Eradication of Marine Leech, *Zeylanicobdella arugamensis* in Marine Groupers Farms. Paper presented in World Aquaculture Singapore 2022, November 29 - December 2, 2022, Singapore https://www.was.org/Meeting/Program/PaperDetail/160153

Wafi D., Cristalina J. M., Wanidawati, T., Ahmed Jalal Khan, C. (2023). Contamination prevention in ASEAN aquaculture: a review of prospective challenges and mitigations. *Desalination and Water Treatment* 315: 523–537 https://doi.org/10.5004/dwt.2023.30018

Wan Norhana, M. N., Kua, B. C. & Liyana, R. (2021). Evaluation of selected plant extracts for in vitro anti marine leech (*Zeylanicobdella arugamensis*) activity. *Tropical Biomedicine* 38(1): 122-129. https://doi.org/10.47665/tb.38.1.021

Wang, Y., Huang, M., Wang, R. & Fu, L. (2018). Complete mitochondrial genome of the fish leech *Zeylanicobdella arugamensis*. *Mitochondrial DNA B Resource*, 3, 659–660. https://doi.org/10.1080/23802359.2017.1372699