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Leveraging scientific knowledge in aquaculture for entrepreneurship - Case studies at Universiti Malaysia Sabah

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Abstract

Aquaculture has emerged as an important sector for addressing the challenge of global food security. In order for it to play this role, certain supporting policies and mechanisms are necessary. Because aquaculture is a subject where there is a convergence of science, art and business, this has a better chance of knowledge-based entrepreneurship. With the demand of seafood steadily rising, the market potential is high to strengthen the business activity related to aquaculture. Aquaculture can be conducted in a wide variety of aquatic environments, whether on land or in the sea, using different methods to produce many kinds of plants and animals for human consumption. This sort of diversity offers entrepreneurship of different types and scales. Not many subjects have as much advantages for entrepreneurship as aquaculture. Government demands that universities in Malaysia should impart entrepreneurship education to students and researchers to commercialize their findings. Aquaculture is one of the niche areas of Universiti Malaysia Sabah (UMS) and thus, it becomes a priority to implement the national policies pertaining to this sector. Steps taken by the University to demonstrate our response through specific case studies are explained in this paper. Borneo Marine Research Institute developed aquaculture as its flagship program of education and research. This included building of infrastructure and expertise. UMS is the only university in the country with two on-campus hatcheries (for finfish and shellfish) to offer education, training and research. Entrepreneurship is an integral part of the undergraduate program. Worthwhile research carried out yielded results of great significance in promoting aquaculture industry. Selection of need-based research topics and problem-solving approaches applied to produce tangible outcomes are highlighted here. The paper also elaborates what it takes to be an aquaculture entrepreneur and constraints of applying industrial model of aquaculture under the academic culture of institutions of higher education. It is evident from an in-depth analysis of the scenario that academic entrepreneurship requires a radical departure from the past practices and a paradigm shift to successfully unify the art, science and business of aquaculture to achieve seafood sustainability and security.

Keywords: Aquaculture, Scientific knowledge, Entrepreneurship, Seafood security

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Introduction

In recent years, university researchers in Malaysia have been increasingly urged to disseminate knowledge, share data, and work with the community and industry to facilitate commercialization of research. Until recently, most academic scientists have not been familiar with marketing, but now they are trying to understand how to translate their intellectual capital into business. Some supporting mechanisms created for such purpose are: protection of intellectual property, monetary and career incentives, funding mechanisms for joint projects, incubator centers, and science and technology parks. Scientists can and will continue to conduct research on topics they are passionate about and evaluate it by considering whether it makes an original contribution to the existing knowledge. However, they are encouraged to look into entrepreneurship opportunities arising from their findings. It appears that the government's push for research and innovations to bolster economies and universities' compulsion to cope with reduced budgets have motivated researchers to explore ways and means of commercializing their research and wading into the entrepreneurship field. It is not just about academic staff becoming more oriented towards entrepreneurship but they are also expected to inculcate this value in students through revamping of course modules, by bringing about necessary changes to the student-centered system of teaching, and structuring research programs accordingly.

Aquaculture is one of those areas where entrepreneurship can pay rich dividends in a conducive environment. For entrepreneurship to take roots, there is a need for a radical change in perspectives and culture to be able to shed the long-held view that commercialization will curtail academic freedom and to overcome the hesitation in taking discoveries to the market. When this happens, scientists will find compatibility between their scholarly and entrepreneurial activities.

Why aquaculture? To answer this question, let us start with the understanding of what constitutes aquaculture. According to Food and Agriculture Organization (FAO), aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding and protection from predators. Farming also implies individual or corporate ownership of the stock being cultivated. Aquatic organisms that are harvested by an individual or corporate body which has owned them throughout the rearing period contribute to aquaculture. This interpretation is significant as it introduces a social dimension, including ownership of the farmed stock and entrepreneurship. The general perception of aquaculture as art, science and business probably strengthens knowledge-based growth of this sector as a profitable business of feeding the world. Because seafood consumption in Malaysia is high (annual per capita consumption = 56.5 kg) and fish is considered not only an important source of high-quality protein but also other substances of health benefits, this creates a favorable environment that supports growth of this sector. Perhaps, this applies to many countries around the world.

The case studies reported here are of very much entrepreneurial relevance and, therefore, of interest to wherever aquatic food security is a topic of national importance.

Role of universities in inculcating entrepreneurship

Universities in Malaysia are governed by the Ministry of Education (MoE) which determines the national policy direction in matters related to tertiary education. The policy guidelines are defined under the 'Malaysia Education Blueprint 2015-2025'. This blueprint has 10 main components called 'shifts' as described below:

1. Holistic, Entrepreneurial and Balanced Graduates- to develop resilience and enterprising spirit for forging new opportunities for themselves and others in an uncertain future.
2. Talent Excellence- to succeed in diversified career pathways.
3. Nation of Lifelong Learners- to meet the changing skill needs by involving individuals who are currently outside the workforce to contribute through empowerment of knowledge in areas they are passionate about.
4. Quality Technical and Vocational Education and Training (TVET) Graduates- to move from a higher education system with a primary focus on university education as the sole pathway to success, to one where academic and TVET pathways are equally rewarding.
5. Financial Sustainability- to lessen financial dependence on government and increase the share of all the stakeholders.
6. Empowered Governance- to encourage institutions of higher learning to strengthen their governance mechanisms to be able to assume a greater responsibility towards growth and development. This will change the Ministry's role as a strict controller to that of policymaker and regulator.
7. Innovation Ecosystem- to move from academia operating in insolation, to academia, industry, government, and local communities forging partnership for the incubation, development, and commercialization of ideas and research findings.
8. Global Prominence- to raise the country's higher education brand, from an attractive destination known for good value for money and quality of life, to one that is also recognized, referred to, and respected internationally for its excellence.
9. Globalized Online Learning- to take advantage of the country's enormous progress in internet penetration in harnessing the power of online learning from a rapid explosion of knowledge to bring innovations for application to produce beneficial outcomes for the country.
10. Transformed Higher Education Delivery- to foster harmonized higher education system focused on delivery, accountability, transparency, and outcomes.

This Blueprint weighs heavily towards entrepreneurship. It is explicit in Shift 1, but its importance is also reflected in Shifts 3, 4 and 7, and to some extent in the remaining ones. This has been further elaborated in the policy document released by the Ministry on 3 April 2018: Framing Malaysian Higher Education 4.0: Future-Proof Talents.

Ministry's policies are relayed to the universities where these are deliberated by the decision-making body (senate) for implementation as far as possible by the faculties, institutes and centers.

To implement and appreciate this policy it is important to know how the entrepreneurship education and training have been helpful in successful business and start-up activities elsewhere. Several researchers who have worked on this matter (Gray and Dennis, 1997; Charney and Libecap, 2003; Cooper et al., 2004; Johansen, 2013) have shed light on the relevance of entrepreneurship ecosystem in institutions of higher education.

Implementation by Borneo Marine Research Institute

Borneo Marine Research Institute (BMRI) is a postgraduate entity and Center of Excellence of UMS. However, the Institute also handles the undergraduate programs of aquaculture and marine science.

Aquaculture is the flagship program of BMRI. In addition to generation of knowledge through research, the Institute gives a great deal of importance to working with the community and the industry, and inculcates entrepreneurship skills in students.

While students learn some elements of entrepreneurship during their undergraduate degree programs through certain courses and industrial training, but research at postgraduate level doesn't embrace entrepreneurship *per se* unless this component is structured in the research topic supported by projects funded by some agency with stipulation about entrepreneurship. Research projects of students pursuing Master's or PhD degree courses have to focus on research and publications. With hard work and motivation they do excel and achieve milestones but do not look for a career in small enterprises with low scale of pay. Moreover, the small and medium enterprises (SMEs) also do not seek candidates with high level of specialization for delivering jobs that can be performed by those not holding high degrees and are willing to accept a lower pay.

Under this situation, academic entrepreneurs must possess a rare blend of skills. They must have the scientific attributes, including inner drive, strength, and technical skills. They need to have the attributes of entrepreneurs, such as the ability to make use of business opportunities, to create value from knowledge and meagre resources, and willingness to take risks. However, not all the subjects of science will stand them in equally good stead in the company jobs in the private sector despite many of these talents. The companies (SMEs) look for skills, especially soft skills, which are good for productivity and income generation. Academic entrepreneurs must, therefore, pursue research endeavors that are most likely to contribute to the bottom line.

Entrepreneurship in undergraduate program

This is embedded in the course module offered by UMS in a structured framework.

- One compulsory course of 3 credits.
- Four months of industrial training where students are attached to aquaculture industry for a compulsory requirement of 8 credits.
- Coordinator of industrial training to handle this program.
- Evaluation done jointly by the host organization and the program coordinator.

For over 10 years our students have been conducting this program in Japan. In Japan, the aquaculture industries provide for maintenance needs but before going to Japan students have to start raising money for the air ticket. They do so by breeding fish and supplying seed to the farmers. In case of fast-growing species, students rear the fish to the harvestable size for marketing.

Entrepreneurship in postgraduate program

There is no general entrepreneurship course for research students registered for postgraduate degrees. They are not like the undergraduate students in one class, but pursue different specialized topics which are typical of the requirements of degree by research. There are topics with entrepreneurship spin-off, and the candidates who decide to pursue the business path are free to do so.

Facilitating entrepreneurship

1. BMRI signs Memorandum-of-Understanding (MoU) with aquaculture industry and other institutions for exchange of business ideas and placement of students for industrial training.
2. Institute also signs Memorandum-of-Agreement (MoA) and Letter of Intent (LoI) with interested industry for contract research on topics of mutual interest.
3. Staff members are encouraged to submit proposals for funding under University-Industry and University-Community grants.
4. BMRI is setting up the 'aquaculture incubator' to facilitate collaboration with the industry and the community.
5. Allows staff attachment with aquaculture industry or institutions of higher learning running industrial aquaculture programs.
6. BMRI have invited other faculties and institutes in UMS under Niche Research Grant Scheme to create demand-driven pathways in emerging areas such as such as smart farming systems, biotechnology, products of industrial applications (bioactive compounds in seaweeds and other marine organisms) and post-harvest technology. The Institute welcomes such collaboration with other academic activities as well.
7. BMRI forges international partnership with for aquaculture commercialization. Worth mentioning is setting up the UMS-Kindai University Aquaculture Development Center on a reciprocal basis.

Research projects of entrepreneurial relevance

Ideally, innovation should be an integral part of entrepreneurship. A recipe for success in business in the twenty-first century in a sector as dynamic as aquaculture is creativity in solving problems. It has to be a continuous and sustained effort in an environment of incessant analysis, putting ideas on trial, analyzing outcomes and even reviewing successful outcomes. These are helpful to fine-tune the future direction and addressing the challenges that might constrain the growth of aquaculture. Such efforts are also necessary for an innovation ecosystem where creative thinking prevails, without the tendency of resting on laurels. It is a long-term commitment but is a requirement for success.

The innovation ecosystem in aquaculture is not only confined to experimental trials but it a culture across the entire organization that breeds, nurtures and rewards the creativity.

A unique combination of critical thinking, creative problem-solving, and entrepreneurship skills can open the door to a range of career options such as starting a new business venture in science, assisting in the commercialization of scientific ideas and patents, or helping to grow an existing knowledge-based industry with a high turnover. Presented below are some specific case studies to demonstrate how the problem-solving research can be helpful in aquaculture entrepreneurship.

Case study- 1
The problem
Unsustainable grouper seed production in hatcheries constraining growth of aquaculture industry
Overfishing and unsustainable methods of exploitation have depleted the population of the much sought-after and high-value grouper species in Sabah. Landings of from capture fisheries are far short of market demand. Hatchery production of seed of giant grouper (*Epinephelus lanceolatus),* which is among the most high-value species, is inadequate and not dependable due to female infertility and other reasons.

Solution
Research was focused on broodstock conditioning, maturity diets, hormonal treatment, and other aspects. An innovative approach that achieved the breakthrough was hybridization of giant grouper male x tiger grouper male (Senoo, 2006; Ch'ng and Senoo, 2008; Luin et al., 2013; Shapawi et al., 2018). It yielded seed that contributed significantly to bridging the gap between supply and demand of the fish.

Entrepreneurial advantage
Availability of quality seed is a key factor in growth of the fish farming industry. Improved seed supply reduces price and enhances the profit margin of farmers, and makes the product more affordable to consumers. This increases investor interest in grouper farming and stimulates entrepreneurial activity throughout the value chain (seed production, grow-out, harvesting, preservation and marketing).

This first-in-the-world outcome of research has boosted grouper aquaculture industry in South-East Asia and beyond.

Hybrids have been subjected to intensive investigations to examine their advantages in terms of resilience to environmental variability, disease resistance and growth, and their adaptability to ocean acidification resulting from changing climate. The ocean simulation experiment established that they are more adaptable to acidification compared to pure stocks (Mustafa et al., 2013). This will help aquaculture industry in its adaptation to climate change.

Case study-2
The problem
Skewed sex ratio due to protogynous condition of groupers making broodstock management expensive and seed supply uncertain
Groupers are protogynous hermaphrodite, i.e., they are born as female and have the ability to change sex to male. Their aquaculture has been hindered by the rarity of male in the natural population. How the grouper gonad undergoes transition from ovary to intersexual condition and then to testis has been the subject of much research interest. Start-up hatcheries face the problem of not easily finding the male grouper. The broodstock of species such as tiger grouper (*Epinephelus fuscoguttatus*) is difficult to obtain, and expensive to buy and to maintain in the hatchery. Breeding fails if male is not available, resulting in economic losses and lack of investor interest due to this risk factor.

Solution
Investigations were made on sex differentiation, especially using hormones. Eventually, it was decided to examine if some cues can trigger sex change and influence the sex ratio in the hatchery tanks. It was observed that unable to find any male in the tank for extended periods when female specimens are gearing up for reproduction causes transitional processes in the gonad of one of the female specimens of the cohort, leading to its sex reversal and differentiation into a functional male. This sex change then suppresses others in the tank from following the same course of events (Mustafa et al., 2015). Breeding then takes place in the hatchery and tiger grouper seed are produced.

Entrepreneurial advantage
Tiger grouper aquaculture will not be hampered due to lack of a functional male in a hatchery. A female can change sex or a differentiated male can be introduced from outside before the female changes into a male fish. It will save time and money, especially for start-ups, to help them remain engaged with broodstock conditioning, especially in supplying fertility ration, while observing the sex differentiation happening through the process as explained.

Case study -3
The problem
Heavy dependence of aquaculture on fish-based feed is adversely affecting the marine ecosystem and capture fisheries, and is likely to undermine the sustainability of aquaculture
Aquaculture of groupers and some other carnivorous species of fish is commercially rewarding to entrepreneurs due to their demand and market value as well as popularity in Live Reef Food Fish Trade (LRFFT). Excessive exploitation of these species has depleted their natural populations and disturbed the coral reef habitat from where they are mainly harvested. Although aquaculture has the potential of increasing the supply but the use of low-value prey fish as feed is placing pressure on the long-term sustainability of capture fisheries. It has a strong impact on the marine biodiversity and ecosystem balance. The price of low value prey fish has seen a sharp increase in recent years and supplies are dwindling due to finite nature of the wild stocks. This is likely to restrict the future expansion of aquaculture if dependence on prey fish does not reduce. Aquaculture industry has also resorted to heavy purchase of pelagic fish such as sardines and mackerels to feed high-value groupers which is undermining the food security of poorer sections of the community that these species have been supporting.

Solution
Solution to this problem lies in developing alternate sources of fish protein and oil from sustainable products. BMRI carried out research for producing diets using non fish-based

components. The replacements have been nutritionally balanced so as not to be deficient in protein and lipid for which prey fish meal and oil have been used. Worth mentioning in this connection are the results obtained using land-based plant and animal products (Lim et al., 2014), poultry byproduct meal (Shapawi et al., 2007; Gunben et al., 2014), vegetable oil (Shapawi et al., 2008), feather meal (Chor et al., 2013), seaweed-based ingredients (Shapawi and Zamri, 2016) and microalgal meal (Shapawi et al., 2017). The ingredients from alternative sources changed the taste of the feed and that reduced its acceptability to the fish. However, after many experimental trials involving taste enhancers, betaine was identified as an effective ingredient (Lim et al., 2016).

Entrepreneurial advantage

This work opened new horizons for formulating eco-friendly feeds and economizing the nutrition of fish grown in culture systems to harvestable size. The novel diets thus produced can help entrepreneurs manufacture them at a commercial scale and to explore new sources of dietary ingredients as well as taste enhancers.

Case study 4

The problem

Negative perception of aquaculture due to environmental degradation and harmful effects on human health

Aquaculture has often been criticized for eutrophication and environmental impacts of effluents in receiving ecosystems, and conversion of mangrove forests into farms. Also, there has been much criticism of treating the farmed stocks with chemicals and antibiotics which posed health hazards to consumers. These issues required solutions in order for this vitally important industry to grow and play a bigger role in global food security. Scientific community has looked into these problems from different perspectives to identify good practices that can contribute to sustainability of aquaculture.

Solutions

1. **Integrated Multi-Trophic Aquaculture (IMTA) -** offers an ecosystem approach to aquatic food production, reduces ecological footprint, excludes the use of harmful chemicals (including the antibiotics) and diversifies business opportunities. This system of aquatic food production is based on integration of complementary species of the trophic chain, where waste from one species becomes food or fertilizer for others. The inorganic component in the waste produced by fed aquaculture species (for example, fish, shrimp, lobster) is used up by heterotrophic/ organic extractive species (for example, sea cucumber, mussel, oyster) whereas the inorganic fraction is assimilated by autotrophic/ inorganic extractive species (for example, seaweed, plants). This creates a balanced and eco-efficient system of biomitigation that augurs well for sustainability. Several projects that were carried out here have resulted in development of many IMTA modules (Mustafa and Shapawi, 2015; Estim and Mustafa, 2010, 2014a,b; Estim, 2015; Sumbing et al., 2015; Saufi et al., 2015).

2. **Ecological sea ranching** – It is a responsible approach that contributes to restoration of marine ecosystem even as it utilizes ecosystem resources for seafood production. This is an appropriate way of mitigating the effects of overfishing in an area over a long period of time that has depleted fish stocks and degraded the marine ecosystem to the extent that their capacity to provide socio-economic benefits has been compromised. It is a direct challenge to food security, poverty alleviation, employment and revenues. Stocking of juveniles of low-food chain species in designated coastal areas restores the spawning biomass of a severely depleted fishery resource to a level where it can recruit to build a population that provides sustainable yield. There are many methods of sea ranching as explained earlier (Mustafa and Taniguchi, 2003). The program on sea cucumber ranching initiated by BMRI in Kudat on the west coast of Sabah links conservation with seafood security and community welfare, and mobilizes the main stakeholders in the ecosystem care for sustainable benefits from the efforts (Mustafa et al., 2017). It reflects the relationships among all ecosystem components, human and nonhuman species, in the rapidly evolving perspective of coupled human-ecological systems. An earlier project involved restocking of shrimp (Annita-Yong et al., 2012). In Kudat, the selected coastal marine area required developing ocean hatcheries for sea cucumber breeding and larval rearing for eventually stocking in the low-energy coastal area (Mustafa et al., 2017). Ecosystem care included habitat protection, biodiversity conservation and water quality management. Sea cucumber was selected because it is a low-food chain species and can live in high density in limited areas without any significant impact on other species or the ecosystem.

Entrepreneurial advantage

IMTA has enormous scope for sustainable entrepreneurship. It maximizes production of organic food per unit area and is thus more profitable. Whereas the fed aquaculture species form the main food item, the plants and seaweed are harvested for human nutrition or as dietary components of animal feed. Organic extractives are generally used as human food. Integrated species synergistically increase total output, even if some stocked species yield less than expected.
Because the generic concept of IMTA covers a large range of practices based on complementarity of multiple species, requiring different farming systems for better outcomes, there is an ample scope for new approaches and modular designs.

Nutrient cascading increases system efficiency and prevents environmental impact. Food produced through IMTA mostly meets the organic aquaculture criteria and this can earn premium price.

Reduction in inputs (use of gravity and solar energy) reduces the cost of production to get a better deal for the entrepreneurs.

IMTA has operational feasibility in remote areas with scarce resources to yield fresh food. It is ideal for SMEs because scale of operation in the form of production modules can be kept under budgetary controls.

Integrated farming imparts stability to production cycle, unlike in monoculture where gains depend entirely on one species that increases the risk factor.

Entrepreneurship can also happen in design of IMTA modules, selection of fed and extractive species, relative biomass of integrated species, nutrient assimilation efficiency, bioremediation efficiency and possibly other aspects of production. These create new employment and growth opportunities. Recent years have seen IMTA entrepreneurs developing technologies and business models for commercial-scale production more than in any other area of aquaculture.

As far as sea ranching is concerned, the only input is that of juveniles of selected species which can be sourced from the wild (under certain conditions) or from hatcheries. Grow-out to harvestable size uses ecosystem resources, with no cost to growers, and the harvest is consumed or marketed. Obviously, it is attracting to entrepreneurs.

Differences in aquaculture programs of universities vs industries

Many universities around the world, including UMS, have demonstrated what they can and cannot accomplish in aquaculture. Aquaculture programs in institutions of higher education have been built with different aims and objectives, fundamentally for teaching, scientific advancement of knowledge and capacity-building. Industries carry out aquaculture for profit. In universities, aquaculture is managed by academic staff (Professors, Associate Professors, Lecturers holding specialized qualifications in nutrition, pathology, water quality, breeding, larval development, and hatchery operations among others) and by many support staff. Industries, on the other hand, look for basic skills, multiple taskers and technicians who can ensure that the operations run without disruptions.

There are many differences right from the beginning when enterprise budget which is developed by listing of all the estimated income and expenses associated with a fish farm to provide an estimate of its profitability. It contains 3 sections: Gross Receipts/ Income, Variable Costs/ Operating Expenses, and Fixed Costs. The first step is to estimate total production (output/ yield) and expected output price. For example, for a hypothetical fish, the estimated production quantity= 1,000 kg, and price of fish is RM 35/kg, the gross receipt = 1,000 x 35 = RM 35,000. Variable costs are the operational expenses, including costs of fingerlings, feed, chemicals, labor, fuel for transport, electricity, repair of facilities and miscellaneous, and interest on operating capital. Fixed costs are the interest on investment (building, equipment), depreciation on building and equipment, and other fixed charges, if any, on building and equipment. Net receipt represents the income which is for the fish farmer. Break-even analysis is a useful tool in enterprise analysis. It is a point at which the total cost and total revenue are equal, or in other words, there is no net loss or gain (zero profit). Universities develop infrastructure and purchase equipment, look after maintenance, pay staff salaries, and bear other expenses. Staff members perform the roles of teaching, research, administration and management. Building and equipment are used not only for generating profit but for teaching, training and research. This is unlike industries where profit-making is the goal. While university hatcheries also produce fish but input costs are difficult to calculate exclusively for net profit calculation. Students pursuing entrepreneurship program do not know or pay costs of electricity and other supplies or rent for building and equipment.

Aquaculture programs of universities are designed for their roles and responsibilities as higher education providers, but they can leverage their capacity to aquaculture industry and entrepreneurship if suitable platforms are created to facilitate mechanisms of cooperation. Reluctance of industries to introduce change in their production approach, methods and technology or to invest in research could be constraining factors in academia-industry collaboration.

Start-up ideas for university graduates

Job market can be tough for fresh graduates. With little first-hand experience, it may not be easy to land the first job which is necessary to gain experience in the first place.
For some candidates, fruitless interviews and open-ended wait for dream job, the entrepreneurship offers better promise. An entrepreneur must have business ideas and capability of building an organization or creating products or services for marketing to make a profit while managing risks that might be involved.

Starting a business generally requires:

1. A business idea or concept regarding products, services, technology or a process that can be marketed.
2. People to support the business, whether as employees, advisors, promoters, vendors or other categories.
3. Developing a system or a process for delivering the product or service or marketing technology.
4. Raising enough support to development of the business plan to the stage at which it generates profit. The most critical is the capital.

Anyone venturing into aquaculture should understand that this business imposes certain costs (Parker, 2002) which are personal or social costs and actual monetary costs. Personal/ Social Costs are:

1. Hard work over long hours, irregular hours, anytime in 24 hours, work on weekends.
2. Extra effort in communicating with people (staff, suppliers, consumers).
3. Get mobilized for emergencies requiring mechanical or electrical troubleshooting.
4. Due to dependence of certain operations, seeking help when needed, even at odd hours.
5. Stand for those on leave or getting replacement rapidly.
6. Making a network of those experienced in handling certain problems that are new to you.
7. Finding time to keep abreast with latest developments that could be in technology, practice and marketing strategies or any other unforeseen matter.
8. Dealing with dynamic security environment.
9. Finding dependable workforce and recruiting when they leave.
10. Processing of legal matters, starting from licensing, operation and product quality among others.

The actual monetary cost is the financial commitment to prevent budgetary risk during the operation of the farm.

Complexity of aquaculture business

Aquaculture is not a simple activity; it is complex and diverse. For a young start-up, the service-based business (consultancy, supplies, transport facility and marketing tools such as website, social media and printing among others) is a good option because it is low-cost, fast and adaptable compared to product-based business. Developing and marketing a physical product (fish, fish feed, hatchery, and others) take time, money and resources.

Main activity in farming is to produce aquatic food but there are allied or supporting companies as listed below:

1. Hatchery equipment – tanks, pipes, pumps, aerators, filters, water quality measurement gadgets.
2. Feed – types.
3. Nets.
4. Ice blocks.
5. Liquid nitrogen, polyethylene bags, oxygen cylinders.
6. Healthcare products- diagnostic kits, treatments.
7. Sea cages, pens.
8. Freezing facilities (cold storage).
9. Packaging.

No aquaculture industry manufactures these facilities all by itself to run the operations- hatchery, nursery and grow-out among others. It is neither economical nor feasible to do so. Obviously, many different companies are a sort of aligned to aquaculture industry to different degrees. For example, feed manufacturing industries are very closely aligned to the extent that these could be counted under the aquaculture sector.

Entrepreneur can contribute to aquaculture industry in many ways:

1. Introduce a new application of technology.
2. Apply a new method, a process or approach.
3. Explore means of minimizing inputs while maximizing outputs.
4. Determine new methods of organic aquaculture and green technology.
5. Produce 'something out of nothing'.
6. Develop new ideas of diversifying existing business, economical spin-off or creating a new business to expand the scope of enterprise.
7. Finding new markets for the product(s).

What is required of aquaculture entrepreneurs is to remain focused on opportunities and solutions (not problems), to strive for never-ending improvement, be mindful of product quality, customer confidence and reputation, be able to take risk and minimize its impact while staying the course for growing business, and learning from mistakes.

Conclusion

Food security concerns will continue to drive aquaculture development. Aquaculture can meet the seafood demand by unifying the science, art and business of cultivating commercially important marine organisms. Recognizing aquaculture as an emerging market with enormous potential for growth, the government of Malaysia has invested heavily in developing infrastructure and capacity building. The challenge now is to commercialize the knowledge that has been generated as a result. National policies embraced by universities have promoted interest in entrepreneurship. Efforts will be needed for radically changing the perspectives of teaching, training and research from generation and dissemination of knowledge to using the knowledge for income generation and contributing significantly to blue growth. Universities dedicated to conducting focused research in aquaculture can find solutions to the problems that help in entrepreneurship ideas but industry ecosystem is needed to harnessing the benefits of innovation. Steady seafood supply will require a sustainable increase in production based on environmental, economic and societal and community considerations. It is difficult to set targets for sustainability because production will vary with species, farming method, geographical area, local cultures and state of knowledge, and technology inputs. The introduction of artificial intelligence as a new tool of managing the aquaculture will have significant implications for production and entrepreneurship. Currently, there are no clear strategies to respond to artificial intelligence revolution that might change the face of contemporary aquaculture. Universities in Malaysia and in many other countries will have to seriously consider ways and means of synergizing the objectives of Malaysian Education Blueprint 2015-2025 and sustainable development goals and expected outcomes elaborated under Malaysian Higher Education 4.0: Future-Proof Talents. Artificial intelligence will certainly find its way in smart aquaculture consistent with the ongoing transformation towards University-Industry 4.0 program. A proactive analysis of the future scenario is thus urgently needed for necessary adaptations in the aquaculture sector.

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