Sustainable Aquaculture Development in Indonesia

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Abstract

Despite the abundance of potential marine resources, including fisheries, Indonesia is still struggling with several issues, particularly in the aquaculture sector. Environmental issues, aquaculture feeds, fish diseases, and exceeding carrying capacity are some of the many challenges that Indonesia must face these days. The Indonesian government through the Directorate General of Aquaculture (DGA), Ministry of Marine Affairs and Fisheries (MMAF), however, has undertaken efforts to overcome the challenges and at the same time ensuring the sustainability of the sector. Sovereign, competitive, and sustainable aquaculture development policies have been implemented through three main aspects of development: 1) production technology, 2) socioeconomics, and 3) natural resources.

Harmonizing and simplifying regulations to encourage investments, interconnecting business chain from downstream to upstream in the industry and strengthening product competitiveness through IndoGAP (Good Aquaculture Practices) implementation are among the steps taken by the government. However, among the efforts to overcome the existing challenges and gaps, Indonesia continues to strive to develop its potential to make Indonesian fish farmers more prosperous and independent in the best possible way.

Keywords: sustainable, aquaculture development, Indonesia

Introduction

Indonesia is a country with abundant natural resources that produces various agricultural, livestock, and fishery products. With the vast area of the Indonesian ocean, the country can produce a large amount of fish and fishery products by capturing fish from the sea. Fishing has been carried out for many years and has become the main livelihood of Indonesian people in several locations, especially in coastal areas. In addition, fishing is becoming important because fishery products are alternative sources of protein and substitute for livestock products such as chicken and beef. However, along with the development of the fishing industry and the growing needs and demands for fish and fishery products, fishing practices are becoming increasingly

unsustainable and uncontrolled. Many fishing industries capture fish in the sea by ignoring the concept of sustainability through overfishing practices, which results in a reduction in stocks. Whereas the need for fishery products is increasing, both in terms of local and export demand. Aquaculture is gradually practiced as an alternative activity to produce fish products. Indonesia itself shows strong potential for aquaculture as the country is comprised of 16,056 islands and has a coastline of around 81,000 kilometers. From the total aquaculture potential area of 17.9 million ha, only 1.3 million is used for aquaculture, which accounts for only 7.4% (Investment Guideline for Sustainable Aquaculture in Indonesia, 2018).

Indonesia is the third-largest producer of aquaculture products in the world as its aquaculture production in 2018 recorded 14.77 metric tons, immediately following China and India (FAO, 2018; The World Bank Group, 2021). Indonesia has been practicing aquaculture many years ago, initially by many families as a backyard activity for additional income. Eventually, the sector developed rapidly and started to become a major source of household income. Aquaculture these days is an important livelihood in rural communities in Indonesia (Rimmer *et al.*, 2013). Given the abundant resources of Indonesia, aquaculture is practiced in three environments: freshwater, brackish water, and marine water. The potential land area for aquaculture is approximately 12 million ha, however, only about 325,825.11 ha is utilized. Given that there is approximately 11,797,558 ha of unutilized area, there are opportunities to develop and implement sustainable aquaculture in these areas (PEMSEA, 2019). Consequently, with the growing practice of aquaculture, more resources were used and have caused impacts on the environment. Therefore, regulations are required to control and manage the sustainability of the sector. In this paper, the existing national and international efforts to achieve a sustainable aquaculture were reviewed. This includes issuance of regulations, cooperation with international organizations, development of new aquaculture technologies, and research and development. The issues and challenges to achieve a sustainable aquaculture as well as the strategies on how to combat these issues were also enumerated.

Sustainable Aquaculture

Conducting aquaculture activities that harmonize with the maintenance of the environment and the safety of its practices is an important concern that can contribute to sustainability. These aquaculture activities include not using prohibited chemicals, not making aquaculture sites near mangroves or on coral reefs, and so on. These are the things that need to be considered and applied by all fish farming communities in Indonesia, both small-scale and industrial, in order to realize the sustainability of aquaculture in Indonesia.

The Indonesian government has made several efforts to realize the sustainability of aquaculture through the issuance of regulations, technical assistance cooperation from regional and international organizations such as FAO, SEAFDEC, NACA, etc. in order to help Indonesia implement good aquaculture practices. Sustainability in aquaculture is not just about the security of its natural resources and the stability of its business but also about how to enhance the capacity of its human resources so that they can do the business in a responsible way. FAO also mentioned that the promotion of sustainable aquaculture development requires that "enabling environments", in particular those aimed at ensuring

continuing human resource development and capacity building, are created and maintained (FAO, 2017). This was then put by FAO into FAO Code of Conduct for Responsible Fisheries which contains principles and provisions in support of sustainable aquaculture development. The Code recognizes the special requirements of developing countries, and Article 5 particularly addresses these needs, especially in the areas of financial and technical assistance, technology transfer, training, and scientific cooperation.

Environment, farmed species, and potential species for culture

Aquaculture is practiced in three environments in Indonesia. These are freshwater, brackish water, and marine water. In freshwater environment, there is a variety of cultured species. Some of the most common freshwater commodities are tilapia, common carp, catfish, pangasius catfish, and gourami. Freshwater fish are highly in demand among Indonesians. These freshwater species are also relatively affordable compared to wild-capture fish like tuna, cakalang, tenggiri, kakap, etc. Apart from the species mentioned above, the government has also encouraged local species to be developed, such as belida, toman, nilem, etc. There is also good potential for freshwater aquaculture in ponds, rice-fish farming, and in open waters such as lakes, swamps and rivers. However, aquaculture in public waters must be done in an environmentally friendly manner, productive, and in accordance with the use of open waters for other purposes. Regulation on carrying capacity is one of the parameters required to preserve environmental sustainability. Meanwhile, the potential land area suited for rice-fish farming is still very large, yet it has not been fully utilized. It is estimated that there are potential rice-fish farming areas as much as about 1.5 million ha throughout Indonesia. Rice-fish farming increases land productivity. There were more yields obtained from harvest of both paddy and fish. It also promotes a more ecosystem-friendly approach to rice farming by reducing the use of pesticides and potentially reduces urbanization and land conversion.

In brackishwater environment, commodities to be cultured are giant tiger shrimp, vannamei shrimp, milkfish, and crab. Brackishwater aquaculture production figures are also quite high, considering the products have their own markets. But when prices are compared, brackish water products still tend to be more expensive than freshwater products.

Mariculture, on the other hand, is a relatively new sub-sector in Indonesia, in contrast to freshwater and brackish water aquaculture, both of which have been practiced for centuries. Given that Indonesia is an archipelagic country comprising around 16,056 islands and has a coastline of around 81,000 kilometers, there are large areas that have considerable potential for mariculture development. However, with such vast potential, about 12,123,383 ha, so far only 328,825 ha have been utilized. The Indonesian government, therefore, has been developing mariculture to utilize the resources as well as to meet the local and export demand for marine products. In marine culture, Indonesia produces some high-value products such as grouper, seabass, seaweed, barramundi, pompano, grouper, and marine ornamental fish. The other major commodity groups are marine finfish and pearl oysters. Potential commodities being developed for mariculture in Indonesia include abalone, sea cucumber, and spiny lobsters.

Aquaculture systems, techniques, and feeding management

Classification of aquaculture practiced in Indonesia based on the number of the species are monoculture, polyculture, and Integrated Multi-trophic Aquaculture (IMTA) in land-based and water-based systems. Each aquaculture environment is using a different system, depending on the scale of the business and the capacity of the environment. Aquaculture is practiced in an extensive (traditional), semi-intensive, and intensive system. Big industries use super-intensive systems to increase production. Freshwater aquaculture is mostly practiced in semi-intensive ponds, floating cages in open waters, and rice-fish farming system on paddy fields. To boost the productivity of freshwater aquaculture, the government has developed technologies to increase production and improve product quality, such as biofloc technology for catfish, mini-recirculation aquaculture system (RAS), and rice-fish farming for tilapia. To address the problem of dependency on imported raw materials as well as to decrease feed cost, the government has made a program of feed self-sufficiency (GERPARI) that focuses on freshwater aquaculture/ commodities.

Brackishwater aquaculture is usually practiced in locations close to brackish or saltwater sources, for example near a beach or estuary to facilitate the filling and replacement of pond water. For locations along the estuary, cage ponds can be made as a practical fisheries investment. As for other ways, earthen ponds, cement ponds, tarpaulin ponds, and plastic ponds can also be made as needed.

Marine culture is one of the fisheries businesses conducted by developing resources in open and closed systems for the culture of marine organisms, either in open sea, closed sea, tanks, ponds, or waterways filled with seawater. A site for marine aquaculture must have certain natural facilities, especially a very adequate water supply, with suitable temperature, salinity, and fertility. Marine aquaculture can be practiced both off-shore and on-shore using cages.

Several technology packages of aquaculture research and engineering are used by fish farmers to improve the quantity, quality, and productivity of aquaculture efficiently. Broodstock center program has produced high-quality breeders from various species and high-quality seeds. Success in the production of vaccines, probiotics, and immunostimulants for fish/shrimp, issuance of Indonesian National Standards in aquaculture, as well as the distribution of fish health and environmental laboratory kits primarily for the early detection of fish diseases owned by the government, private sector and universities have enhanced the growth of aquaculture business effort.

One of the examples of government support towards the development of aquaculture technology that is currently underway is the application of shrimp ponds clustering in order to develop principles of responsible, environment-friendly, and sustainable aquaculture that is managed based on its carrying capacity. Through clustering, the technical side of the application of biosecurity will be more stringent, and the management of aquaculture waste and conservation-based cultivation will be more effective. These will directly prevent the occurrence of pests and shrimp diseases and minimize the impact of aquaculture on existing ecosystems. It also ensures that shrimp products can be highly competitive in the global market.

Production, consumer demand, cost of production, profitability

Aquaculture production in Indonesia is quite significant. It reached up to 16,114,991 tonnes in 2017. It comprised freshwater culture at 3,531,686 tonnes (22%), brackishwater culture at 2,698,635 tonnes (17%), and marine culture at 9,884,670 tonnes (61%) (PEMSEA, 2019).

From 2010-2014, the trend of aquaculture production has been increasing with an average growth rate of 23.73%. The trend of aquaculture production is presented in **Figure 1.**

Consequently, the contribution of fisheries to the national economy of Indonesia showed an increase from 2014–2018. The share of fisheries to the country's GDP in 2014 is 2.32% and increased to 2.60% in 2018 (**Figure 2)** (PEMSEA, 2019). And under fisheries, it was reported that the share of aquaculture in 2017 reached 56.4% of the total national fisheries GDP (Statistics Indonesia, 2018). This indicates that aquaculture can boost the national fisheries economic performance. From 2011-2015, aquaculture commodities showed significant increase. These commodities include seaweed (21.29%), shrimp (15.08%), fish (14.28%), and shellfish (9.94%) (**Table 1**) (PEMSEA, 2019).

The increase was due to several priority activities initiated by the government, namely: biofloc technology, rice-fish farming, feed self-sufficiency programs, and other technical assistance provided by DGA.

Based on the aquaculture production by commodity (**Table 1)**, marine culture production is higher than freshwater and brackishwater. However, the number is bigger for seaweed production rather than fish production. Moreover, it was reported that the total aquaculture production from marine aquaculture activities reached up to 9 million tons for seaweed commodities and the rest of 138 thousand tons for fish commodities in 2017. Thus, marine culture still must be developed further, given that the prospects appear positive. Indonesia still has great opportunities in developing marine culture. This can be seen from the existing potential area covering 12.1 million hectares while utilization is only about 285,527 hectares.

Therefore, the Indonesian government has been putting significant effort to develop marine culture production by improving the technology and enhancing the capacity for marine culture development. Indonesia has several advantages for mariculture development, including many potential mariculture sites, a stable tropical climate,

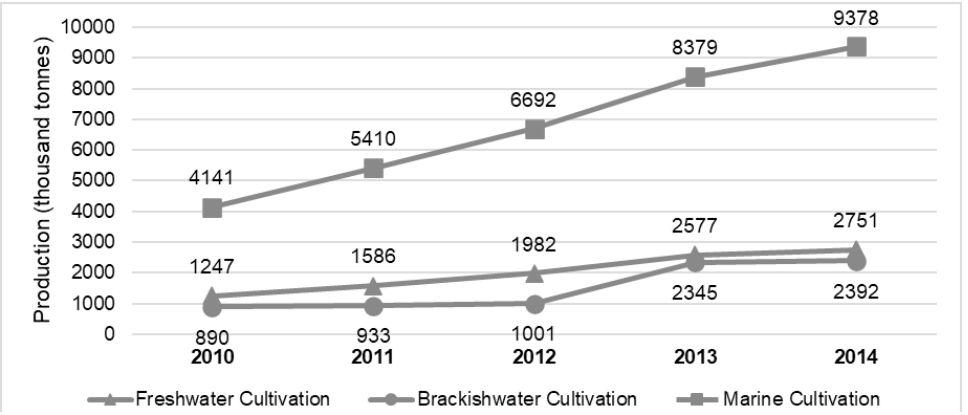

Figure 1. Trend of Aquaculture Production in Indonesia from 2010-2014 (PEMSEA, 2019)

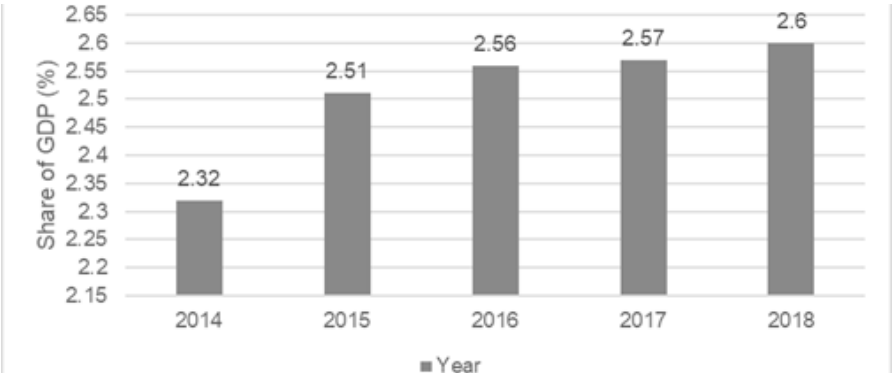

Figure 2. Contribution of Fisheries to the Gross Domestic Product (GDP) in Indonesia from 2014 to 2018 (PEMSEA, 2019)

Table 1. Aquaculture Production by Commodity from 2011-2015 (PEMSEA, 2019)

Commodity	2011	2012	2013	2014	2015	Growth 2011-2015 (% per year)
Seaweed	5,170,201	6,514,854	9,298,474	10,076,992	10,890,326	21.29
Shrimp	372,577	415,703	642,568	639,369	605,328	15.08
Black tiger	126,157	117,888	178,583	131,809	124,869	3.37
Vannamei	246,420	251,763	390,278	442,380	413,079	15.98
Other shrimp		46,052	73,707	65,180	67,381	17.29
Fish	2,068,472	2,550,255	3,116,988	3,390,080	3,486,917	14.28
Grouper	10,580	11,950	18,864	13,346	15,638	14.68
Seabass	5,236	6,198	6,735	5,447	5,123	0.49
Milkfish	467,449	518,939	627,333	631,125	668,262	9.60
Carp	332,206	374,366	412,703	434,653	461,882	8.63
Tilapia	567,078	695,063	914,778	999,695	1,068,604	17.59
Gourami	64,252	84,681	94,605	118,776	113,258	16.10
Pangasius	229,267	347,000	410,883	418,002	339,095	13.15
Catfish	337,577	441,217	543,774	679,379	722,657	21.31
Pompano			643	1,367	2,663	103.66
Silver barb	11,966	19,074	24,107	26,994	24,760	22.37
Bonylip barb	22,552	25,426	27,668	32,080	29,565	7.42
Giant snakehead	14,273	19,886	24,642	21,024	28,112	20.57
Shellfish	48,449	19,472	29,091	44,394	43,312	9.94
Others	269,264	175,269	213,785	208,295	200,351	-4.83
TOTAL	**7,928,963**	**9,675,553**	**13,300,906**	**14,359,129**	**15,226,234**	

and does not suffer from cyclonic storms. Globally, the demand for seafood products is expanding due to the increasing population and increased per capita consumption of fish products. Thus, the Indonesian government has been putting significant efforts to increase marine aquaculture production by developing the mariculture sector through the installation of off-shore cages in several locations in Indonesia.

Freshwater commodity such as African catfish (lele) is one of the most consumed and preferred fish by middle-class society in Indonesia. The African catfish dishes can easily be found everywhere, from a street food stall to a bigger restaurant. Apart from relatively more affordable, freshwater fish also tastes as good as seafoods. As a result, many fish farmers seize the business opportunity in freshwater aquaculture. For illustration, African catfish is one of the best-selling commodities in Indonesia. The cost of production and business analysis for extensive catfish culture using tarpaulin pool for small-scale/household business is provided below in **Table 2**.

With the assumption of up to 90% recovery rate, the initial 2000 catfish seeds stocked, harvest can reach up to 1800 pieces or about 500 kg. Given a market price of African catfish at about 10,000 Indonesian Rupiah (IDR)/kg (lowest price), harvest can yield up to 5,000,000 IDR. The price of African catfish range between 10,000 – 15,000 IDR per kg, depending on location and demand. Considering a production cost of 1,100,000 IDR, the net profit would be 3,900,000 IDR (Fatoni, 2016). This profit is for the first harvest. The next harvest can provide a bigger profit because pond installation cost has been deducted already from the first harvest. Prices also vary across cities, thereby affecting profit. However, this computation did not include labor cost and land rent. Also, note that this example used a tarpaulin pond with minimum capital. For businesses with bigger capital, a concrete pond can be built and used to co-culture African catfish with other freshwater commodities.

Table 2. The cost of production and business analysis for extensive catfish culture using tarpaulin pool (Fatoni, 2016)

Commodity	African catfish (IDR)
Initial capital	950,000
Tarpauline	600,000
Bamboo	300,000
Nails	10,000
Others	40,000
Production cost	1,100,000
Seeds (± 2000)	500,000
Feeds	500,000
Vaccine and Vitamin	100,000
Total	**2,050,000**

Issues and challenges

Indonesia still has to face several global challenges that require immediate action to solve the barriers to its sustainability. Issues and challenges encountered in the development of aquaculture can be identified and grouped into five big themes as follows:

Production system

a. Distribution of information and implementation of recommended technology have not been fully reached aquaculture business units in Indonesia due to the limited number of advisor (advance fish farmers) in the district. Technological guidance and assistance in mariculture areas have not been done intensively due to the remote location of certain areas.

b. Acceleration of Good Aquaculture Practices (GAqP/CBIB) certification is still an issue due to lack of socialization, assistance on GAqP application by facilitator/district service to fish farming units, fish farmers' lack of comprehension on GAqP standards and criteria, and that GAqP certificate is still done voluntarily and has no value-added for fish farmers who have applied the standard and criteria of GAqP, due to low acceptance of GAqP certificate in aquaculture processing units (UPI);

c. The application of GAqP in the aquaculture industry will also lead to the assurance of product safety, which does not exist yet in the industry, mainly for small-scale enterprises. Therefore, GAqP requires effort to solve the traceability issue of aquaculture products in Indonesia.

d. The price of registered fish feed is relatively expensive because most of the raw material are imported and are affected by dollar exchange rate and also influenced by "3F"- food, feed and fuel issues. Consequently, some fish farmers still use the relatively cheap unregistered fish feeds which are often of low quality.

Hatchery system

a. Limited information and distribution of high-quality broodstock and seed are among the issues in developing hatchery systems.

b. Low and inconsistent supply and poor quality of seeds. The development of seed supply systems is also constrained by the under utilization of facilities and infrastructure that have been built, mainly BBI/BBIP/BBUG (fish and shrimp hatchery) due to of lack of qualified human resources.

Infrastructure and facility system

The main constraint in the development of infrastructure system is limited infrastructure, such as water channel, both input/output that is damaged by siltation, difficult access to electricity network in aquaculture locations, difficult access road in aquaculture production location. In addition to infrastructure, limitations in aquaculture facilities have also become a constraint in the development of aquaculture systems.

Business system

One of the challenges in the development of a business system is capital, especially for the development of brackish water aquaculture or mariculture that requires substantial capital. Bank trust is still low towards fish farming. Bank requirements are quite difficult, thus access to capital for fish farming is also difficult. Another constraint is the institutional management system of POKDAKAN (fish farmers group) that has not developed well. Thus, weakening the bargaining position of fish farmers in terms of marketing.

Fish health and environment system

a. Diseases remain the main constraint in the development of a fish health system. Additionally, environmental degradation has also become an issue caused by uncontrolled pollution from other business sectors.

b. One of the most pressing environmental concerns on the development of aquaculture activity in Indonesia is the growing number of floating cages in lakes and reservoirs. The rapid development of floating cages activity has become more excessive and uncontrolled over the years. Thus, damaging the sustainability of the aquatic

environment that threatens the sustainability of floating cages. The problems are as follow:

i. Pollution and eutrophication from fish farming waste activities (fish droppings and leftover feeds). Pollution from human activities around the environment and upstream watershed.

ii. Frequent cases of mass mortalities farmed fish due to the up-welling phenomenon or the rise of the bottom layer of waters that contain many toxic substances to the surface.

iii. Excess carrying-capacity. Most cage culture activities have exceeded the environmental carrying capacity and caused some risk due to mortality and decreased production such as in Lake Toba (Maninjau) and Reservoir Cirata (Cirata, Saguling Darma).

iv. Excessive and uncontrolled cage activities spoil the tourism opportunities in the area.

Strategies

Product improvement through innovation technology

a. Aquaculture using biofloc system which is a technology for intensive culture based on the oxygen supply and specific floc microorganism.

b. Rice-fish farming to optimize use of field irrigation to increase production.

c. Fish feed self-sufficiency program where the fish farmers to are encouraged to produce their own feed using local raw material to save the cost of production. The government aids in the form of equipment and tools, together with expert advice.

d. The development of off-shore cage culture is one of MMAF's strategic programs to increase marine fish production. Target production from this sector reaches up to 2,448 tonnes per year of barramundi with an economic value of 13 million USD per year.

e. Recirculating aquaculture system (RAS) is an intensive fish farming system that uses infrastructure that allows the use of recirculated water. It applies filter physics, filter biology, UV, oxygen generator to control and stabilize the environmental condition, reduce the amount of water use, increase survival rates, and use of limited areas. With this RAS technology, the Freshwater Center in Tatelu, South Sulawesi was able to boost tilapia stocking rate up to 5,000 fish/m^3, while stocking density in conventional systems only reaches 50 fish/m^2. Productivity can be increased up to 100 times in the RAS system compared to the conventional system.

f. Seaweed tissue culture method or *in vitro* vegetative propagation technique to produce high-quality explants. The carrageenan content of seaweeds produced through tissue culture reaches up to 40% with an average LPH of 11.50%.

g. Fish resource preservation through fisheries management and restocking in open waters to increase fish population and preserve the diversity of fish resources.

Capacity building

Capacity building is one of the government's concerns to enhance human resources capacity both in knowledge and skills, particularly in aquaculture. The staff of the DGA and the fish farmers are subjected to capacity enhancement through trainings and workshops. The Ministry of Maritime Affairs and Fisheries (MMAF) works together with related institutions and partner countries in holding trainings and workshops on aquaculture.

Product improvement

The MMAF seeks to encourage the issue of traceability and food safety in aquaculture products to be addressed through process and product certification from upstream to downstream.

i. To ensure the availability of seeds, MMAF has established broodstock centers for the Jepara Brackish Aquaculture Aquaculture Center (BBPBAP) as a broodstock center and the tiger shrimp nauplii Center and merguensis, while the superior Shrimp Main Production Center and Shrimp (BPIU2K) Karangsem as vannamei shrimp broodstock center. Besides that, KKP is also trying to maintain the quality of shrimp broodstock through the issuance of Circular Letter (SE) prohibiting the use of parent from ponds.

ii. SNI development and aquaculture certification system (INDO GAP/ GAqP). The implementation of the GAqP system is very important as a guarantee that the aquaculture products produced are safe for consumption. GAqP is a series of considerations, procedures, and protocols designed to ensure that aquaculture activity is practiced in a controlled environment by taking into account sanitation, feed, medicine, biological materials, and chemicals (Kamaruddin *et al*., 2015). Currently, the Indonesian GAqP version has been harmonized with FAO guidelines on aquaculture certification, ASEAN shrimp GAP, and ASEAN GAqP guidelines.

Zoning

a. Environmental modeling and GIS-based tools for carrying capacity study to conduct site selection for appropriate aquaculture activity.

b. Cluster-based aquaculture which an integrated aquaculture management based on carrying capacity that is carried out collectively. A cluster approach is also considered as an effort to attaining group certification, thereby relieving small-scale farmers of the burden of bearing the high cost for this purpose (NACA, 2011). The benefit of implementing this system is to better control aquaculture management, such as a more stringent biosecurity system; better pond layout; more effective control of pest and fish diseases; better management of waste; and guaranteed traceability of production system.

Collaborative projects, government-initiated collaborative projects through several cooperation schemes, some of the recent collaborations are as follows:

i. FAO

a. Scaling-up of innovative rice-fish farming and climate change resilient Tilapia pond culture practices for blue growth in Asia (TCP/RAS/3603)

b. Supporting local fish feed self-sufficiency for inland aquaculture development in Indonesia (TCP/INS/3606)

c. Support mitigation of Antimicrobial Resistance (AMR) risk associated with aquaculture in Asia. (TCP/RAS/3702)

d. Traceability for shrimp farms (TCP/INS/3704)

ii. RI – Norwegia through Sustainable Marine Aquaculture Development in Indonesia (SMADI) project that works on 4 (four) themes: 1) marine spatial planning and carrying capacity; 2) disease and parasite control; 3) breeding and 4) technical standard for integrated off-shore aquaculture. This collaboration is implemented under the grant scheme provided by the Norwegian government. The purpose of this project is to assist the Indonesian government in sustainably developing the marine aquaculture sector by enhancing Indonesian administration and management systems.

Research and development

Some of the researches that have been done by the Research and Development Department under MMAF to support the DGA's program and activities are as follows:

i. Development of feed formula for increasing production and productivity of freshwater broodstock, 2015, Jojo Subagja, Mas Tri Djoko Sunarno, Research and Development Center for Freshwater Aquaculture, Sempur, Bogor.

ii. Pangasius culture (*Pangasionodon hypopthalmus*) based on local raw material feed, 2015, Ani Widiyati, Mas Tri Djoko Sunarno, Research and Development Center for Freshwater Aquaculture, Sempur, Bogor.

iii. Utilization of aquaculture recirculation system (RAS) for vannamei shrimp culture, 2013, Permana Ari Soejarwo, Center for Research and Engineering of Marine and Fisheries Technology, Indramayu, Jawa Tengah.

iv. *Gracilaria gigas* seaweed seed production technology with tissue culture method, 2015, Petrus Rani Pong Cook, Research and Development Workshop for Seaweed Culture, North Minahasa, Sulawesi.

v. Production of superior seeds of *Gracilaria* spp. seaweed through tissue culture, propagation in ponds and multi-location tests in the aquaculture center area, 2013, Rohama Daud, Sri Redjeki Hesti Mulyaningrum, Emma Suryati, Syarifuddin Tonnek, Research Center for Development of Brackish Water Aquaculture, Takalar, Sulawesi.

vi. Intensive production of superior fish in rice-fish farming land, 2012, Irin Iriana Kusnini, Otong Zenal Arifin, Vitas Atmadi Prakoso, Wahyulia Cahyanti, Freshwater Aquaculture Research and Development Center, Sempur, Bogor.

vii. Increased rice-fish farming productivity using organic fertilizers, 2012, Ani Widiyati, Yosmaniar, Adang

Saputra, Imam Taufik, Research Institute for Freshwater Aquaculture and Development, Sempur, Bogor.

viii. Intensification of Nila Best using biofloc technology, 2011, Yohanna Retnaning Widyastuti, Imam Taufik, Sutrisno, Research Institute for Freshwater Cultivation and Development, Sempur, Bogor.

ix. Application test of biofloc-forming heterotrophic bacteria in tilapia nursery, 2016, Eri Setiadi, Yohanna Retnaning Widyastuti, Ani Widiyati, Angela Mariana Lusiastuti, Research Center for Freshwater Aquaculture Fisheries and Fisheries Education, Sempur, Bogor.

However, more researches are still needed, particularly on marine aquaculture, to further study the feasibility of the marine aquaculture activity, the industry, and the impact of the activity on the environment.

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