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Some Current Trends and Challenges in Philippine Aquaculture, with an Emphasis on Synergies with Biodiversity Initiatives

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In local public wet markets in the Philippines, wild-captured and aquacultured fish, crustaceans and plants are sold to avid consumers (Photo: J.A. Ragaza).

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The Philippines is an archipelago in Southeast Asia with a total land and water area of about 300,000 km^2. Bounded by major bodies of water on all sides, the country has a thriving fishing industry. The contribution of fisheries to the Gross Domestic Product in 2015 was 1.5 percent, which translates to US$3.8 billion (DA-BFAR 2015). In 2014, the country ranked twelfth in global marine capture fisheries, with a total output of 2.14 million t of marine products, or 2.6 percent of the world's total production of 81.55 million t (FAO 2016).

Most of the total fish produced by the country in 2015 is from the aquaculture sector, which accounted for 2.35 million t or 51 percent of the total, valued at US$1.85 billion (DA-BFAR 2015). Oysters, mussels and seaweeds account for 1.60 million t (68 percent) of aquaculture production (Table 1). Philippine mariculture is primarily seaweed farming; seaweeds account for 1.57 million out of 1.60 million t (98 percent). By sheer quantity, seaweeds are the top aquaculture product of the country, making up 67 percent of all aquaculture fisheries production in 2015. The Philippines was third after China and Indonesia in production of aquatic plants, including seaweeds.

Among the three environments for aquaculture (freshwater, brackishwater, marine), the greatest production is in brackish water, which contributes 325,633 t or 14 percent of the total. Of this production, 99 percent is from ponds. Fresh water is the second most common environment for Philippine aquaculture, contributing 303,126 t of production (13 percent of total), most of it also in ponds. Most marine aquaculture systems are fish cages. In 2014, the Philippines ranked fifth in the world in terms of total aquaculture production of finfishes, molluscs, crustaceans, other aquatic animals and aquatic plants (FAO 2016).

Brackishwater fish pond systems are primarily used to grow

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As the Philippines is surrounded by water, fishing villages are common throughout the country. This is a fishing village in the municipality of Binmaley in Pangasinan, which is located at the northern part of the Philippines. (Photo: Janice A. Ragaza)

Seahorse farming by the AQD of SEAFDEC aims to improve broodstock reproduction and survival and growth of juveniles (Photo: J.A. Ragaza).

Oysters and mussels account for more than 65 percent of aquaculture production in the Philippines. (Photo: J.A. Ragaza)

milkfish *Chanos chanos*; 227,815 out of the total 323,629 t (70 percent) produced in these environments are milkfish (DA-BFAR 2015). Milkfish production also dominates brackishwater fish cages and fish pens. Milkfish also accounts for most of the production in marine fish pens at 104,924 out of 105,606 t or 99 percent. Tilapia production comprises 142,339 out of 147,569 t (96 percent) of freshwater fish ponds and tops all other freshwater systems.

Considerable quantities of materials used for aquaculture are imported by the Philippines every year. Shrimp feeds (6,313 t) come from Vietnam (77 percent) and Taiwan (17 percent) were valued at US$65,800 in 2015 (DA-BFAR 2015). That same year, 19,029 t of feeds for fish, crustaceans, and molluscs valued at US$118,400 were imported.

Tables 2 and 3 show recent programs and projects by the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD) and the Food and Agriculture Organization of the United Nations (FAO), respectively.

Environmental Impacts and Potential Solutions, Including "Wildlife Farming"

Historically, a key concern regarding aquaculture is its environmental impact. Among the major negative effects of

TABLE 1. Proportion of aquaculture production in the Philippines in 2015 across culture environments. Modified from DA-BFAR 2015.

Culture environment	Quantity (t)	Percentage of total
Mariculture (oysters, mussels, seaweeds)	1,602,572	68
Brackishwater	325,633	14
Freshwater	303,126	13
Marine water	116,755	5
Small-farm reservoirs	72	<1
Rice fish	3.5	<1
TOTAL	2,348,162	100

Philippine mariculture is primarily seaweed farming. Caulerpa lentillifera, *commonly known as sea grapes, is grown on several seaweed farms in the country (Photo: J.A. Ragaza).*

Culture of different species of shrimps has been facing the challenge of production loss due to various diseases (Photo: J.A. Ragaza).

aquaculture on ecosystems are: 1) the proliferation of invasive species, 2) eutrophication of waters by effluents from the production system, 3) conversion of vulnerable and valuable natural ecosystems for aquaculture use, 4) transmission of diseases and 5) pressure on wild fish populations for production of fishmeal (Diana 2009).

The degradation of water quality in ecosystems supporting aquaculture is still a major concern in the Philippines, particularly on the island of Luzon. In Taal Lake, concentrations of total dissolved solids, nitrates, and phosphates are significantly greater in samples from aquaculture cage sites than in areas without such activities (Querijero and Mercurio 2016). Although water temperature, pH, salinity, transparency and dissolved oxygen (DO) did not significantly differ between the two areas over the 10-mo study period, DO and transparency were consistently lower where aquaculture was being practiced, with DO reaching a critical low in January and February. In mariculture areas around Bolinao and Anda, waters continued to be eutrophic, as indicated by high dissolved inorganic phosphorus concentration, some ten years after regulations were imposed to restrict the number of farming operations due to a harmful algal bloom and massive fish kill in the

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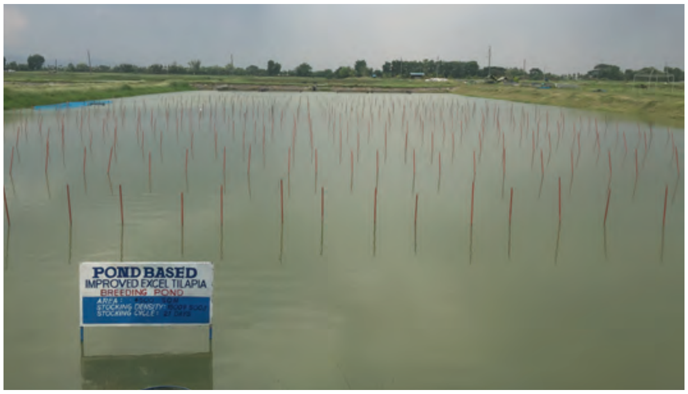
TABLE 2. Themes of SEAFDEC/AQD research and development programs in the Philippines in 2015. Modified from SEAFDEC/AQD (2016).

Program themes	*Number of programs*
Producing quality seed for sustainable aquaculture	23
Promoting healthy and wholesome aquaculture	23
Maintaining environmental integrity through responsible aquaculture	6
Meeting social and economic challenges in aquaculture	4
Reinforcement and optimization of fish health management and effective dissemination in the Southeast Asian Region	5
Environment-friendly, sustainable utilization and management of fisheries and aquaculture resources	4



Tilapia production tops all other freshwater systems in the country, making up more than 95 percent of the freshwater fish ponds. This photo shows a breeding pond for the improved Excel tilapia in BFAR, Nueva Ecija, Philippines (Photo: J.A. Ragaza).

area in 2002 (Ferrera *et al.* 2016). Eutrophication was largely the result of the over-abundance of fish farm structures, at twice the allowable number set by the local government.

Impacts on biodiversity remain a concern, particularly where there is potential for invasive species being involved in disruption of ecosystem functions. Aquaculture sites in Laguna de Bay, the largest inland freshwater body in the Philippines, have significantly lower species richness, species evenness and relative dominance of native species (Cuvin-Aralar 2016). The SEAFDEC/AQD (2016) has four research and development programs related to biodiversity, including one that investigates the impact of aquaculture on the biodiversity of aquatic fauna near the Binangonan Freshwater Station. The three other programs involve ranching of seahorses and sea cucumbers, two of the most heavily exploited animal taxa in the illegal wildlife trade.

Wildlife farming, which is the legal commercial domestication and breeding of traded organisms, has become popular in recent years among conservationists because of its potential to reduce pressure on wild populations of exploited fauna and flora (Tensen 2016). Seahorse and sea cucumber ranching done in the Philippines for purposes of supplying the trade, which is mostly for traditional Chinese medicine (Domínguez-Godino *et al.* 2015, Yasue *et al.* 2015), are examples of wildlife farming, although the term has not been used locally to describe such operations. The country has been recognized for large-scale rearing of the seahorse species *Hippocampus kuda* and *H. trimaculatus*, with novel set-ups involving floating bamboo and nylon mesh cages for grow-out of juveniles (Koldewey and Martin-Smith 2010). Ursua and Azuma (2016) report seahorse farming operations run by SEAFDEC/AQD have seen improvements in broodstock reproduction as well as in survival and growth of newborn and juvenile seahorses through ultraviolet sterilization of water and formalin treatment of feeds.

The aquaculture industry may lend itself well to the wildlife farming model and contribute to a reduction of pressure on coral reefs from wild harvest of marine ornamentals. This is because of the existing capability for closed cycle systems for cultured species, general feasibility, and its being incentive driven; fisherfolk's success in aquaculture will reduce their reliance on wild stocks. A financial feasibility analysis has shown that an integrated, full-cycle aquaculture system for the common clownfish *Amphiprion ocellaris*, a staple of the marine ornamental trade, can be profitable, although small-scale fisherfolk would need subsidies to meet the high initial capital investment and subsequent operating costs (Pomeroy and Balboa 2004).

Disease Risks and Mitigation

Diseases have long plagued aquaculture all over the world. In 2013, diseases were considered the most important challenge in global shrimp aquaculture (Anderson and Valderrama 2013). Tropical shrimp aquaculture may be in a crisis of lost production induced by diseases, with the major threats being white spot syndrome virus (WSSV), infectious hypodermal and hematopoietic necrosis virus, and early mortality syndrome, also known as acute hepatopancreatic necrosis disease (AHPND). Contrary to traditional views, Doyle (2015) has suggested that inbreeding among farmed shrimps has caused significant depression in their resistance to disease and climate stress and so biosecurity and genetic enhancement programs should be promoted. There are also reports of emerging diseases in local shrimp aquaculture, such as the abdominal segment deformity disease, that had previously been known only among cultured white shrimp *Litopenaeus vannamei* in Thailand (Santander-Avancena *et al.* 2017).

Such problems are not limited to shrimps, of course. A study in Taal Lake by Hallare *et al*. (2016) showed significantly more micronuclei and nuclear abnormalities in Nile tilapia *Oreochromis niloticus* in aquaculture sites compared to non-aquaculture sites, perhaps due to un-ionized ammonia and copper in bottom sediments where tilapia feed.

The concern over diseases in aquaculture persists, even as improvements to biosecurity continue to develop. In 2015, there were at least ten research and development programs by SEAFDEC/AQD on monitoring, diagnosis, investigation, reduction and treatment of diseases across different finfish and shellfish species (SEAFDEC 2016; Table 2). In May 2015, the FAO began to fund a local project meant to raise awareness on and control of AHPND in farmed shrimp (FAO 2017; Table 3). Another project began in January 2017 with the objective of strengthening capacities, policies, and national action plans concerning aquatic antimicrobial resistance.

Molecular Techniques for Improving Aquaculture Practices

With the rise in ubiquity of molecular techniques in biological disciplines, aquaculture has also been increasingly turning to these tools to improve practices. DNA-based markers have been used to determine stock characteristics and monitor stock quality, including determining rates of inbreeding, identifying specific markers correlated with fitness and comparing wild and hatchery stocks (Romana-Eguia *et al*. 2015). In milkfish, microsatellite markers were developed from 24 loci (Santos *et al.* 2015). Of the 72 markers developed, nine showed high success rate in amplification and polymorphism. These markers can be used for genetic stock discrimination and monitoring.

Molecular techniques also are used in the fight against diseases. Next-generation sequencing and suppression subtractive hybridization was used to find genes associated with higher survival rates against WSSV in shrimp (Maralit *et al.* 2014). Hemocyanin, ferritin, and fortilin-binding protein showed differential expressions between surviving shrimp and control shrimp of some genes that are associated with bacterial infection and environmental stress.

The SEAFDEC/AQD had several programs involving molecular tools for aquaculture, including one on development of diagnostic tools for shrimp pathogens using nested PCR and lateral flow strip biosensors and another on development and application of molecular markers in broodstock management of milkfish (SEAFDEC/AQD 2016).

Climate Change Effects on Aquaculture

Higher water temperatures are detrimental to egg survival of milkfish, Asian seabass and rabbitfish (SEAFDEC/AQD 2016). Also, because of its geographical location and geologic history, the Philippines is at high risk from natural hazards like typhoons (Andriesse and Lee 2017). The exposure of the country and its resources to storms has necessitated more research on how extreme weather events affect the resources themselves and their economic characteristics. The Philippines is at a high risk of fisheries-related food security problems associated with climate change (Ding *et al.* 2017). This is the result of the high dependence of the population on marine fisheries for nutrition and the reliance of the Philippine aquaculture on high employment in marine fisheries. Viability of the seaweed value chain in Iloilo in the face of recurring typhoons is limited (Andriesse and Lee 2017). Since the devastating typhoon Yolanda (Hainan) in 2003, farmers have had to rely on inefficient horizontal coordination with fisherfolk associations and support from international civil society organizations. Enhanced information dissemination and greater cooperation with the public sector are essential. What makes the problem worse is that many of the other issues faced by aquaculture, such as proliferation of invasive species and diseases and biodiversity losses, are closely coupled with and can be exacerbated by climate change (Williams *et al.* 2016, Ding *et al*. 2017).

The FAO and the Philippines national government have recognized the need for aquaculture to address the emerging problems brought about by climate change. Among the existing projects of the FAO in the Philippines is one aimed at building capacity for climate-resilience in farmed tilapia and another on enhancing climate-resilient agri-fisheries (FAO 2017; Table 3). The SEAFDEC/AQD (2016) also has several projects under the theme of adapting to climate change.

Prospects for the Future

In the Regional Technical Consultation on Sustainable Aquaculture Development in Southeast Asia Towards 2020 hosted by the SEAFDEC in Tigbauan, Iloilo in 2011, the panel identified four key themes or crucial issues that will be faced by the aquaculture industry in the coming years: 1) social and economic challenges, 2) quality seed production for sustainability, 3) a "healthy and wholesome" industry, and 4) environmental protection and adaptation to climate change (Acosta *et al.* 2011). For aquaculture in the country to truly flourish, it has to be truly responsive to these issues.

Given increasing awareness of the link between aquaculture and biodiversity, the Philippine Biodiversity Strategy and Action Plan (PBSAP), which is the country's obligation as a party state to the Convention on Biological Diversity (CBD), offers unique opportunities. Table 4 shows program interventions in the PBSAP that are related to aquaculture. Many of these are collaborations among different entities, including private groups and government agencies. They also enable the Philippines to meet the 2020 Aichi Biodiversity Targets set by the CBD and the Department of Environment and Natural Resources-Biodiversity Management Bureau of the Philippines national government. This is indicative of the synergy that the aquaculture industry must achieve within its own management structures and with other sectors to address the multidimensional problems that it continues to encounter.

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TABLE 3. FAO aquaculture projects in the Philippines. Modified from FAO (2017).

Project title	*Start and end years*	*Donor/s*	*Budget (in US$)*
Building capacities for a climate resilient tilapia farming in the Philippines	2015 to 2017	FAO	226,000
Reducing and managing the risks of Acute Hepatopancreatic Necrosis Disease (AHPND) of cultured shrimp	2015 to 2017	FAO	422,000
Strengthening capacities, policies and national action plans on aquatic AMR	2017	Multilateral: Netherlands	566,714
Support for enhancing climate-resilient agri-fisheries in the Philippines	2017	Philippines	4,107,659
Promote scaling-up of innovative rice-fish farming and climate resilient tilapia pond culture practices for blue growth in Asia	2017 to 2018	FAO	490,000

TABLE 4. Program interventions, targets, and indicators related to aquaculture in the Philippine Biodiversity Strategy and Action Plan 2018-2025, with corresponding 2020 Aichi Biodiversity Targets and PBSAP Targets addressed. Taken from DENR-BMB (2016).

Program intervention	*Targets*	*Indicators*	*Responsible entity/ies (*lead)*	*2020 Aichi Biodiversity Targets†*	*PBSAP Targets*
Improve capacities of local stakeholders including IPs, women and youth and communities to control and limit overexploitation and destructive practices on fisheries and aquaculture	Local policies/ ordinances on regulated use of coastal and marine resources are formulated and implemented	Trends in the destructive practices on fisheries, agriculture, aquaculture and forestry resources	Local Government Units (LGUs)*, Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR), Academia	6 By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.	9 By 2028, there will be an annual increase of at least 5% in Biodiversity conservation related jobs (ecotourism, sustainable agriculture, ecosystem restoration).
Undertake research on priority areas of concern	Research is undertaken on the following: a) carrying capacities (programmatic) for ecotourism, mariculture, aquaculture; b) life history characteristics of priority species (fecundity and reproductive patterns)	Research results are available for use by policy makers and other relevant sectors	Department of Environment and Natural Resources-Ecosystems Research and Development Bureau (DENR-ERDB)*, Department of Environment and Natural Resources-Biodiversity Management Bureau (DENR-BMB)	4 By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.	18 By 2028, there will be a 10% annual increase from the 2015 baseline in the number of schools, POs, media organizations, LGU, private companies, policy makers, government offices that are aware and supportive of biodiversity, its importance, threats and benefits of protecting it.

Notes

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TABLE 4. CONTINUED

Program intervention	*Targets*	*Indicators*	*Responsible entity/ies (*lead)*	*2020 Aichi Biodiversity Targets†*	*PBSAP Targets*
Reduce pollution from aquaculture activities	The Codes of Conduct for Good Aquaculture Practices and for Responsible Fisheries are implemented	Water and soil quality	DA-BFAR*, Private sector, LGUs, Department of Science and Technology-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD), Academe, civil society organizations (CSOs)	8 By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.	10 By 2028, the key threats to biodiversity will be reduced, controlled or managed.
	The ban on harmful chemicals used in aquaculture (eg. organotin and molusciscides) is enforced	Water and soil quality	DA-BFAR*, LGUs, Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB)	8	10
	Incentives to use environment friendly alternatives are provided	Incentives for use of environment-friendly molluscicides and other similar pest control chemicals	DA-BFAR*, DENR-EMB, LGUs	8	10
		Alternatives to harmful chemicals	DA-BFAR, DOST*, DENR-EMB, LGUs	8	10
Implement sustainable aquaculture practices in inland wetlands	Policies on sustainable aquaculture (FAO Code of Conduct for Responsible Fisheries and other Codes of Conduct for Sustainable Aquaculture, BFAR AO1- 2008, Wildlife Act) are promoted and implemented	Percentage of aquaculture permittees practicing sustainable aquaculture	DA-BFAR*, DENR-BMB, Department of Trade and Industry (DTI), Department of Interior and Local Government (DILG), LGUs	6	17 By 2020, relevant biodiversity conservation policies to address existing gaps are in place.
Develop and implement methods, tools and technologies for wetland management	A scheme to phase out aquaculture in NIPAS sites that existed before RA 7586 is formulated in consultation with stakeholders and implementation is initiated	Phase-out guidelines	DENR-BMB*, DA-BFAR	6	17
		Percentage aquaculture activities in NIPAS sites	DENR-BMB*, DA-BFAR	6	17

† *Taken from the CBD (2017)*

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