Strategies for Boosting Aquaculture Development in Southeast Asia

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While the global population is increasing, many people have become more concerned about their health and are looking for nutritional products. Seafood is the preferred choice of many people around the world in view of its nutritional values. In 2006, the world's food fish production was around 160 million mt of which 83 million mt was from marine capture fisheries, 67 million mt from aquaculture while 10 million mt was from inland capture fisheries. By 2020, it has been predicted that the world's demand for food fish would need an additional 40-60 million mt (de Silva, 2008).

In 2006, the Southeast Asian countries shared about 15% (24.0 million mt) of the world's total fish production (capture and culture combined). With a total aquaculture production of 8.3 million mt in 2006, which has dramatically advanced during the last five years, Southeast Asia accounted for more than 12% of the world's total production from aquaculture (**Table 1**).

The top five aquaculture producing Southeast Asian countries in 2006 were Indonesia (26.5%), Philippines (25.2%), Vietnam (20.3%), Thailand (16.7%), and Myanmar (6.9%) with the remaining 4.4% shared by Cambodia, Malaysia, Lao PDR, and Singapore. The major economically important species being cultured in the region are shrimps and prawns, catfish, marine fishes, carps and barbs, marine mollusks, milkfish, and seaweeds. Due to their economic significance, crustaceans have been the main cultured species in the region, with a very rapid growth demonstrated during the recent years. In terms of value, production from

Table 1. Contribution from Southeast Asian countries to the world's total fish production (2002-2006) in million metric tons (mt)

	2002	2003	2004	2005	2006
Southeast Asian Production	18.682	19.850	21.238	22.674	23.948
Inland Fisheries	1.514	1.481	1.559	1.639	1.890
Marine Fisheries	12.552	13.119	13.294	13.426	13.762
Aquaculture	4.616	5.250	6.385	7.609	8.296
World's Total Production	146.485	146.981	155.822	157.803	159.897
Inland Fisheries	8.718	8.958	8.922	8.716	10.069
Marine Fisheries	85.798	82.821	87.033	85.788	83.081
Aquaculture	51.969	55.202	59.867	63.299	66.747

***Source:** FAO FishStat Plus 2008*

the culture of highly-priced crustaceans had an increased share of 45% of the region's total fish production followed by freshwater fishes at 41%.

Aquaculture Production Profile and Opportunities for Development in Southeast Asia

A review of the leading aquaculture producing countries in Southeast Asia showed that there are opportunities and potentials for sustainable development of the aquaculture industry. Specifically, Thailand has been the world leader in shrimp aquaculture since 1994 accounting for around 20-25% of the shrimps in the world market (Ekmaharaj, 2006). The country's total area available for aquaculture is around 70,000 ha with total annual production of about 1.4 million mt out of which shrimp production is nearly 40% (about 500,000 mt annually).

Penaeid shrimps and freshwater prawns

The two major species of marine penaeid shrimps which accounted for over 60% of the region's total crustacean production in 2006 are the white-leg shrimp, *Penaeus vannamei* and the giant tiger shrimp, *P. monodon* (Lymer *et al.*, 2008) with production of about 0.50, 0.35 and 0.34 thousand mt coming from Thailand, Vietnam and Indonesia, respectively. However, these countries have also experienced fluctuations in their annual production primarily due to the impact of viral diseases.

In Thailand, reduction of the farm gate selling price for shrimps pushed the country's area for aquaculture to decrease. As a result, there have been cases where the use of ponds has been diversified to oil palm plantation, rice culture or culture of other fish species such as sea bass or freshwater prawns. Considering the experiences that the Thai fish farmers have over the years in terms of good farm practices, their products are however, more diversified to include frozen products and a wide range of value-added products that boost better marketing chances not only in domestic markets but also in the export market arena.

Vietnam has around 580,464 ha of aquaculture farm areas with a total annual production from aquaculture of about 1,660,000 mt of which shrimp production in 2006 was about 349,000 mt (SEAFDEC Fishery Statistical Bulletin, 2009). However, there is diversity in the species being cultured in the country, *i.e.* temperate species such as *Peneaus indicus* in the northern part, *P. vannamei* in the central part, and *P. monodon* in the southern part. The country's shrimp culture system makes use of small ponds operated on a per family basis making it difficult to adapt good farming practices such as having seawater storage and effluent treatment pond for each small units. Although disease outbreaks have become a related problem, the farmers have signified interests in learning new technologies to mitigate such problem.

In Indonesia, there are around 127,681 ha of aquaculture farm areas giving a total aquaculture production of about 2,377,500 mt/year of which shrimp production is about 340,000 mt (SEAFDEC Fishery Statistical Bulletin, 2009). Aquaculture is mostly operated using traditional or semi-intensive practices, although intensive systems could be promoted if the fish farmers are provided with appropriate training in advanced aquaculture technologies. As a matter of fact, there is a great potential that the country's overall yield (kg/ha) could increase, and if realized could make Indonesia the leading Southeast Asian country in terms of cultured shrimps export in the next 5-10 years.

Freshwater prawn *Macrobranchium rosenbergii* also forms part of the shrimp and prawn products cultured in and exported from the region. Thailand, Indonesia, Malaysia and Myanmar are the top producers in Southeast Asia with annual production of about 29.50, 1.20, and 0.20 thousand mt, respectively (Lymer *et al.*, 2008). Within the Southeast Asian region, the freshwater prawn has also good potentials in domestic markets.

Marine fishes

Marine fish culture in Southeast Asia is dominated by sea bass (*Lates calcarifer*), grouper and snapper. Sea bass is the major cultured species with the highest production followed by grouper and snapper, ranking second and third. At least 16 species of groupers are being cultured in Indonesia, Malaysia, Philippines, Thailand, and Vietnam (Lymer *et al.*, 2008). Thailand has the highest production from culture of marine fishes at 12,202 thousand mt in 2002 increasing to 31,016 mt in 2005 (SEAFDEC Fishery Statistical Bulletin, 2009). However, Thailand's production dropped to 18,346 mt in 2006. The same pattern was also observed in the production from marine fish culture of Indonesia and Malaysia during the same period (**Table 2**).

Marine mollusks

Marine mollusks, which are mostly cultured traditionally in coastal waters, comprise the green mussel (*Perna viridis*), oysters and blood cockle. Production of mollusks also fluctuated from year to year (**Table 3**). Thailand accounted for the highest production of 400,400 mt in 2004 but such production seemed to be decreasing by about 10% annually (SEAFDEC Fishery Statistical Bulletin, 2009).

Table 2. Production from marine fish culture in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Thailand	12,202	14,568	16,945	31,016	18,346
Indonesia	11,518	14,145	4,751	9,428	5,315
Malaysia	5,214	6,188	8,511	8,760	4,336
Singapore	247	304	349	461	450
Philippines	121	449	172	199	242

***Source:** SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Table 3. Production of cultured marine mollusks in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Thailand	382,918	357,937	400,400	346,636	314,116
Vietnam	-	-	155,235	143,800	146,200
Malaysia	84,913	79,025	72,731	67,425	53,496
Philippines	24,216	28,000	30,953	36,654	36,566
Indonesia	7	2,869	-	16,348	19,632
Singapore	2,903	2,362	2,396	2,958	5,955
Cambodia	414	524	590	400	500
Myanmar	-	-	-	778	-

***Source:** SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Table 4. Production of catfish in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Thailand	86,482	101,618	159,337	140,650	147,287
Indonesia	49,457	71,518	21,836	57,798	60,158
Malaysia	12,656	15,924	19,188	19,186	19,448
Philippines	2,634	2,163	1,390	2,355	2,376
Brunei Darussalam	...	...	27	27	30

***Source:** SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Milkfish

Popularly cultured in the Philippines and Indonesia, milkfish (*Chanos chanos*) can be farmed in freshwater, brackishwater and marine environments. Philippines is the number one producer of milkfish in Southeast Asia with total production of around 315,074 mt in 2006, followed by Indonesia at 212,922 mt. Although traditionally produced in brackishwater ponds, there is now an increasing trend towards mariculture of milkfish, indicating the use of more intensive marine cage culture systems (Lymer *et al.*, 2008).

Tilapia

Although tilapia (*Oreochromis niloticus*) is an exotic species in the Southeast Asian region, it has become a very important species cultured in many Southeast Asian countries, namely: Indonesia, Philippines, Thailand, Malaysia, Lao PDR, and Myanmar. The annual production in 2006 of the region's top six producers was 0.98, 0.19, 0.16, 0.11, 0.29, 0.20, and 0.02 thousand mt, respectively (Lymer *et al.*, 2008). Tilapia can be produced both traditionally and intensively and can be marketed locally and exported to other countries.

Catfish

The catfish species commonly cultured in Southeast Asia is the *Clarias* catfish, which is mainly produced from the hybrid catfish. The four producers of *Clarias* catfish are Thailand, Indonesia, Malaysia, and Philippines with a total production of 229,299 mt in 2006 indicating an increase of about 20.50% since 2002 (**Table 4**). Thailand started to report its catfish production only in 2006 which comprises 37.8% of the total production in the region (SEAFDEC Fishery Statistical Bulletin, 2009).

Another catfish species produced in the region is the *Pangasius* catfish, which is mainly produced in Vietnam. Recently, a very dramatic increase in the production of the *Pangasius* catfish was observed in Vietnam, notably the tra (*Pangasius hypophthalmus*) and basa (*Pangasius bocourti*) (**Table 5**). The country's production area for the *Pangasius* catfish is mainly located in the Mekong River Delta in southern Vietnam. In 2006, Vietnam's production of *Pangasius* catfish reached a record of 450,000 mt (SEAFDEC Fishery Statistical Bulletin, 2009). Following such trend, FAO (Lymer *et al.*, 2008) forecasted that the country's production will surpass 1.0 million mt in 2008. On the other hand, the country's export data on the Pangasius catfish also indicated a very rapid increase considering that its target market has shifted from the USA to the European Union which now accounts for more than 50% of the country's export in terms of quantity.

Other freshwater species

Carps (Chinese carp) and barbs (Cyprinids)
Carps and barbs are among the most popular freshwater species cultured in some countries in Southeast Asia such as Indonesia, Myanmar, Thailand, and Lao PDR. Myanmar can be considered as a newly emerging aquaculture nation in Asia, especially in terms of production from the culture of barb species such as the *Labeo rohita* (Rohu). Aye *et al.* (2007) cited that the aquaculture production of Myanmar accounted for approximately 22% of the total production from its fisheries sector in 2005-2006. The country's aquaculture production increased significantly in the last decade and the great bulk came mainly from the culture of Rohu. The country's production is particularly important in terms of supplying the source of protein for the populace in rural areas thus, could also be considered as an approach towards poverty alleviation. In 2007, the country's total export from freshwater aquaculture was around 76,303 mt of which production of Rohu was about 59,600 mt (Department of Fisheries of Myanmar, 2008).

Snakehead (Family Channidae)
The total production of snakehead in 2006 in Southeast Asia was 12,115 mt with Thailand, Philippines and Malaysia as the top three producing countries (**Table 6**). Production trends increased from 2002 to 2005 but decreased in 2006 (SEAFDEC Fishery Statistical Bulletin, 2009). Popular only in few countries like Thailand, snakehead does not have a large export market and has minimum potentials in the regional markets of Southeast Asia, where the fish is generally sold live or whole (Lymer *et al.*, 2008).

Aquatic Plants
Aquatic plants cultured in the Southeast Asian region are the biopolymers such as *Eucheuma cottonii*, *Kappaphycus alvarezzi*, *Gracillaria* spp, red seaweeds, and others (Lymer *et al.*, 2008). The Philippines has the highest production of aquatic plants which was about 1,468,906 mt in 2006, followed closely by Indonesia at 1,374,462 mt (**Table 7**).

Table 5. Production of *Pangasius* catfish in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Vietnam	135,000	163,000	255,000	376,000	450,000
Indonesia	...	...	23,692	31,488	31,488
Thailand	14,837	23,085	30,626	28,000	22,470
Myanmar	500	800	5,000	5,000	10,000
Cambodia	...	...	3,000	5,000	8,000
Malaysia	3,000	4,282	4,925	5,500	5,524

Source: *SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Table 6. Production of snakehead in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Thailand	5,577	4,205	10,420	12,507	9,438
Philippines	...	1,388	1,272	1,256	1,230
Malaysia	1,329	804	1,163	924	1,057
Singapore	455	535	417	416	303
Indonesia	1,031	970	...	...	87

Source: *SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Table 7. Production of seaweeds in 2002-2006 (mt)

Country	2002	2003	2004	2005	2006
Philippines	894,857	988,888	1,204,808	1,338,597	1,468,906
Indonesia	223,080	233,156	734,573	866,383	1,374,462
Malaysia	25,625	27,608	30,957	31,426	43,200
Vietnam	...	...	...	30,000	30,000
Cambodia	3,650	7,800	16,840	...	...

Source: *SEAFDEC Fishery Statistical Bulletin for the South China Sea Area 2006 (2009)*

Concerns and Strategies for Sustainable Aquaculture Development

Notwithstanding the rapid growth of the region's aquaculture sector, it is being continuously confronted with many constraints that include, among others: oil price fluctuation, unstable and inconsistent production, impact of climate change, and disease outbreaks. However, strategies can be proposed for boosting the sustainable development of aquaculture in the Southeast Asian region.

Since majority of the people in the rural areas are small-scale farmers, the role of rural aquaculture in providing means of livelihood and ensuring sustainable food supply is becoming very significant and hence should be enhanced. Moreover, the development of mitigation measures on the impact of climate change to aquaculture development would be one of the most significant strategies for the sustainable development of aquaculture. Considering that most of the shrimps, Pangasius catfish, barbs and others produced from the region are mainly for export, eco-labeling the products with traceability would be another strategy so that the region's products could best compete in the world market.

The region's aquaculture sector should also adopt the ecosystem-based approach to aquaculture (EAA) under the FAO initiatives, as guideline for minimizing the environmental and social impacts from aquaculture. Research works on specific pathogen free/resistant broodstocks, new candidate species for aquaculture and alternative protein sources for fish feeds should also be intensified to be able to provide the scientific information necessary in carrying out the important strategies for the sustainable development of aquaculture in the region. Lastly, equally important is human resources development (HRD) in the aquaculture sector which should focus on the capacity building of both human resources in the government sector as well as technicians from the private sector and fish farmers, for advance technologies in order to attain high economic returns from implementing the environmental and social friendly operations along with the requirements stipulated in the EAA approach.

Issues and Constraints in Aquaculture

The very fluctuating oil prices have significant impact on the aquaculture sector as this leads to increasing costs of inputs and other costs such as feeds and transportation, making it very risky for fish farmers to continue their operations. Although aquaculture production appears increasing, but the farm gate price of aquaculture products is decreasing resulting in less profits for the fish farmers. Ventures to increase stocking density in ponds have been tried, but in many cases such attempts led to more frequent water pollution followed by diseases outbreaks. On top of this, the farmers still have to face the impacts of other natural disasters such as floods and storms. Recent demands by importers and consumers to trace the products (traceability) throughout the production chain, has led to the demand for products to be eco-labeled (Ekmaharaj, 2006). This in turn adds more costs on the part of the fish farmers although meeting such requirements could also provide increased foreign market opportunities. Furthermore, in order to mitigate environmental impacts and address social concerns, some improvements on farm routine practices are needed but this could potentially mean more investment costs on the part of the fish farmers.

Strategies for Aquaculture Development

Rural aquaculture for poverty alleviation

The increasing number of fish farmers and aquaculturists particularly in Asia during the past three decades, growing much faster than in the traditional employment in agriculture, is a reflection of strong expansion of aquaculture activities. In 2004 for example, fish farmers accounted for about 25% of the total number of workers in the fisheries sector.

Moreover, in a situation where fishery resources from the wild are over-exploited and affected by multiple water resource use and pollution, the role of freshwater aquaculture in providing means of livelihood and ensuring sustainable food supply in remote rural areas has become very apparent. Thus, it is a key challenge to develop freshwater aquaculture approaches that could open up livelihood opportunities for the rural poor, who could not go easily into aquaculture mainly because of lack of access to capital and resources, vulnerability and aversion to risks (Bueno, 2008). To enable the rural farmers to adopt, operate and sustain relevant aquaculture practices, they would require access to appropriate skills including knowledge in advance technological and management practices, land and water, financial capital, organizational arrangements, physical facilities, and infrastructures.

In an effort to address such concern, SEAFDEC identified community-based aquaculture as an approach to look into the collective needs of the rural fisheries communities. Under this strategy, SEAFDEC focuses on capacity building where existing regional competence and experiences are compiled and thereafter shared among the countries in the region for adoption based on their respective conditions. This is envisaged to promote appropriate aquaculture systems in the remote rural areas in Southeast Asia where most people appeared have long been ignored due to their isolation from the most basic infrastructures.

Mitigating the impacts of climate change to aquaculture

Climate change has threatened aquaculture activities specifically on the aquatic species being cultured, land/coastal use, energy use as well as on feed supply. On the other hand, aquaculture activities could also influence some changes in the environment. Thus, people involved in aquaculture are sure to face uncertainties in terms of availability of resources and exposure to extreme climate change. SEAFDEC has identified major potential adaptive measures to mitigate the impacts of climate change in aquaculture (**Box 1**).

Box 1. Potential adaptive measures to mitigate the impacts of climate change on aquaculture

Elements of climatic change (CC)	Impacts on aquaculture or related functions	Adaptive measures
Warming	• Raise above optimal range of tolerance of farmed species • Increase in growth: higher production • Increase in eutrophication and upwelling, mortality of farmed stock • Increase virulence of dormant pathogens and occurrence of new diseases • Limitations on fish meal and fish oil supply/price	• Use better feeds, more care in handling, selective breeding and genetic improvements for higher temperature tolerance (and other related conditions) • Increase feed input; adjust harvest and market schedules • Improve planning and siting to conform to CC predictions; establish regular monitoring and emergency procedures • Focus management to reduce stress; set up biosecurity measures; monitor to reduce health risks; improve treatments, management strategies; make genetic improvements for higher resistance • Identify fish meal and fish oil replacement; develop new forms of feed management, make genetic improvement for alternative feeds; shift to non-carnivorous species; culture bivalves and seaweeds wherever possible
Sea level rise and other circulation changes	• Intrusion of salt water • Loss of agricultural land • Reduced catches from coastal fisheries, seedstock disruptions, reduced options for aquaculture feeds; income loss to fishers • Increase of harmful algal blooms (HABs)	• Shift to stenohaline species upstream; introduce marine or euryhaline species in old facilities • Provide alternative livelihoods through aquaculture, building capacity and infrastructure • Make greater use of hatchery seeds; protect nursery habitats; develop/use formulated pellet feeds (higher cost but less environmentally degrading); develop alternative livelihoods for suppliers • Improve monitoring and early warning systems, change water obstruction points where possible
Acidification	• Impact on calcareous shell formation/deposition	• Adapt production and handling techniques; move production zones
Water stress and drought conditions	• Limitations for freshwater obstruction • Change in water-retention period (inland systems reduced, coastal lagoons increased) • Reduced availability and period change of wild seedstocks	• Improve efficacy of water usage; encourage non-consumptive water use in aquaculture, e.g. culture-based fisheries; encourage development of mariculture where possible • Use different/faster growing fish species; increase efficacy of water sharing with primary users, e.g. irrigation of rice paddy; change species in lagoons • Shift to artificially-propagated seeds (extra cost); improve seed quality and production efficiency; close the life cycle of more farmed species
Extreme weather events	• Destruction of facilities; loss of stocks; loss of business; mass scale escape which could potentially impact on biodiversity	• Encourage uptake of individual/cluster insurance; improve siting and design to minimize damage, loss and mass escapes; encourage use of indigenous species to minimize impacts on biodiversity, use non-reproducing stock in farming systems

Considering that aquaculture species are poikilothermic (body temperature changes with the surrounding water), changes in habitat temperatures affect their growth rate, total production, reproduction pattern, and vulnerability to diseases and toxins. Such changes also affect the aquatic species used for feed production. Improved management and better aquaculture practices would be the best and most immediate forms of adaptation. Integrating aquaculture with other practices, including agro-aquaculture, multi-trophic aquaculture and culture-based fisheries, could also offer the possibility of recycling nutrients and using energy and water much more efficiently. Using new species or strains and new technologies or management practices to fit new opportunities is also another option. Aquaculture could also have a role in bio-fuel production through the use of algal biomass or discards and by-products of fish processing.

As fisheries provide significant feed and seed inputs, the impacts of climate change on them will also in turn, affect aquaculture production. Adaptations include changing to less carnivorous species, genetic improvements, feed source diversification, better formulation, quality control, and management. However, trade-offs with other uses (food, bio-fuel, etc.) need to be clearly understood at regional and local levels.

Aquaculture has a relatively small overall CO_2 carbon foot print. Aquaculture of freshwater herbivorous or omnivorous species would require at most small amounts of fertilizer and in some cases, low-energy supplementary feeds. On the other hand, some species and systems such as shrimps and marine carnivores have high feed energy or system energy demands, and consequently higher footprints. Lastly, in the events of extreme weather changes, escapes of farmed stock could occur which could contribute to reduction in genetic diversity of the wild stock, affecting biodiversity more widely.

Mitigating environmental impacts and promoting social welfare

Aquaculture in the Southeast Asian region is mostly small-scale. Hence, some products have often been rejected by importing countries as these are considered below the minimum quality level. Since aquaculture has always been blamed for the deteriorating environment, a series of product quality standards have been required by many importing countries such as the USA and by the European Union (EU). The Southeast Asian countries aiming to export considerable quantity of products for more foreign exchange earnings, are now adopting measures to mitigate the various environmental impacts. Such mitigation strategies include the development of certification in aquaculture by promoting eco-labeling, aquaculture zoning, information management and traceability (Lymer *et al.*, 2008).

While some countries have developed policies for aquaculture expansion, more often than not these resulted in environmental degradation and occurrence of diseases outbreaks. Therefore, attempts are being made to separate the aquaculture areas into zones, where the site of each species such as marine shrimps are zoned to prevent the impact of saline water and other effluents that will have impact to the agriculture fields and the coastal ecosystem. The EAA being advanced by FAO (Soto and Hishamunda, 2008) is guided by three key principles, namely: (i) aquaculture should be developed in the context of ecosystem functions and services with no degradation of the ecosystem beyond its resilience capacity; (ii) aquaculture should improve human well-being and equity for all relevant stakeholders; and (iii) aquaculture should be developed in the context of (and integrated to) other relevant sectors. Correspondingly, the three scales/levels of EAA applications have been identified as the farm; the water body and its watershed/aquaculture zone; and the global market size scale. Thus, the concept of EAA has been considered an approach that could mitigate the impacts of aquaculture to the environment.

Furthermore, along with the requirements for product quality and residue management, importing countries now require products to be traceable. Therefore, a product traceability system from farm to finished products is now being developed by the countries in the region, although the development is still at a considerably slow pace. Traceability systems are highly dependent on effective information systems based in the geographic locations of the producers, processors and markets; and efficient documentation processes to ensure that the products are clearly identified from point of production to point of sale.

Research on new aquaculture technologies

Pollution and new disease outbreak have constrained the sustainability of aquaculture often leading to great losses on the part of the fish farmers. Research on aquaculture system management and disease prevention are therefore needed. Some countries have policies to increase aquaculture production by increasing stocking density and expanding aquaculture areas. Increasing stocks would require the use of more feeds leading to water pollution which is usually followed by diseases outbreaks. Research on aquaculture system management should also aim to decrease feed conversion ratio (FCR) and reduce the use of feeds through better feed management (Platon *et al.*, 2007). The use of specific pathogen free and resistant (SPF/SPR) fry/fingerlings could be another option to reduce the risk in farming practices. For example, the white-leg shrimp (*P. vannamei*) can now be domesticated and spawned to produce SPF/SPR fry/fingerlings. In fact, it is for this reason that the culture of white-leg shrimp has also expanded very rapidly in the Southeast Asia region.

Food fish is more popular with increasing high demand, and by 2020 world demands would require an extra 40-60 million mt of food fish. Research to propagate potential wild species could also deliver such demand in the future. The more potential species being laid out for aquaculture would give more chances for people to get into aquaculture, especially the rural people. This could mean better opportunities for providing livelihood and ensuring sustainable supply of food fish in the rural areas.

Alternative materials to be used in the production of aquaculture feeds should be examined. Jackson (2007) reported that 5 to 7 million mt of fishmeal had been produced each year some of which are used as aquaculture feed. FAO (Lymer *et al.*, 2008) has set the general principles of fish as feeds in order to avoid the high demand of transforming fish into feeds. Research on alternative materials as substitute to fishmeal in feeds should be undertaken to decrease the use of fish food which in turn could also reduce fishing by-catch. The result can be beneficial both for fishery conservation and fish farm operations because having alternative ingredients as protein sources in feed formulations could be cheaper than using fishmeal.

Human Resource Development

Human resource development is a strategy that enables all stakeholders to develop and improve their skills, knowledge, and abilities. It could include training, extension, increasing awareness on relevant information, and focuses on the over-all development in order that individual fishers can accomplish the goals of sustainability from the points of view of social and economic aspects of fisheries. In aquaculture for example, human resource development is important so that the stakeholders would become aware and

would be able to adopt the various fisheries instruments, commitments and requirements, *e.g.* the Code of Conduct for Responsible Fisheries, EAA as well as the recently evolving international market-driven requirements, *e.g.*, eco-labeling and traceability. One of the major aspects of sustainability is responsible fisheries management practices. To be able to implement such practices would require improved skills and human capacity on the part of all the stakeholders. Considering also that fact that the success in fisheries management could be attained through participatory approach in co-management, human resource development would play an important role as new levels of capacity are required to enable the fishing communities and resource users to participate in the co-management aspect.

Conclusions

The sustainable development of aquaculture has been constrained with various factors and the demand for eco-labeling aquatic products and traceability documentation requirements of importing countries has made the concerns more complicated. Strategies should therefore be developed for aquaculture in Southeast Asia in order to sustain the region's export quantity and quality as well as enhance the supply quality and enough quantity of fish products for the region's populace. The advancement of rural aquaculture in the region for poverty alleviation could reduce the gap between the region's increasing number of fishers and the food supply. Mitigation measures should also be implemented to address the impacts of climate change on aquaculture as well as the possible environmental and social impacts of aquaculture. Research on new aquaculture technologies, creation of new products and value-adding for export should also be explored. Finally, human resource development should be promoted as the stakeholders need to improve their skills on the various aspects of the aquaculture operations in order to be able to adapt and adopt the various fishery instruments, commitments and requirements, and above all to be able to take part in the co-management.

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