FISH for the PEOPLE

A Special Publication for the Promotion of Sustainable Fisheries for Food Security in the ASEAN Region
Volume 13 Number 2: 2015
Bangkok, Thailand, ISSN: 1685-6546

SEAFDEC at 48:

Enhancing the Marketability of Fish and Fishery Products from Southeast Asia

Southeast Asian Fisheries Development Center

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Production of this publication is supported by the Japanese Trust Fund.

Editorial

Business Dictionary defines marketability as the "*relative ease at which an item or product could be sold for a price at which similar items or products are selling*". This implies that in the trading arena, there is a need to enhance the quality of products in order to increase their marketability as consumers are now choosing quality products over equally priced less-quality products. In the fisheries sector, SEAFDEC has been promoting the marketability of fish and fishery products from Southeast Asia, based on three major approaches. First, is by advocating healthy and wholesome aquaculture; second, by ensuring the safety and quality of fish and fishery products; and third, by improving management for sustainable fisheries. By pursuing these approaches, the fish and fishery products from the region could easily comply with the requirements of the various measures and instruments directed towards the sustainability of fisheries.

At 48, SEAFDEC continues to reap and amass adequate technologies that would arm the Southeast Asian stakeholders with methodologies and systems to support their efforts in undertaking sustainable fisheries and aquaculture as well as in coming up with safe and quality fish and fishery products that would eventually secure the niche of their products in the regional and global markets. To continue with the chronicle of achievements of SEAFDEC during the 48 years of its existence, this issue would drum up the marketability of fish and fishery products from Southeast Asia through the promotion of healthy and wholesome aquaculture which has been championed by the Aquaculture Department (AQD), and the development of safe, nutritious and quality fish and fishery products being espoused by the Marine Fisheries Research Department (MFRD) through improved and optimum utilization of the fishery resources. Overall, SEAFDEC as an R&D organization has been working towards the improvement of management for sustainable fisheries and socio-economic stability in the Southeast Asian region.

Since its establishment in 1973 in the Philippines, AQD has been putting emphasis in addressing concerns on food safety and the sustainability of aquaculture in Southeast Asia considering the unstable supply of fish products from capture fisheries and the advantages of consuming seafood over animal meat for health reasons. Since aquaculture could fill the gap between supply and demand of fish and fishery products, it has to be healthy and wholesome, which entails optimizing production through innovations in fish nutrition and fish health management, while preserving the integrity of the aquaculture environment. In advocating healthy and wholesome aquaculture as a holistic approach towards attaining sustainable aquaculture, AQD has placed more focus in the development and refinement of protocols for diagnosis, prevention, control, and treatment of diseases in fish; establishment of measures aimed at getting out of the "fish meal trap" by reducing dependence on fish meal in aquaculture feeds; and the adoption of environment-friendly culture practices that are economically viable and socially equitable.

Starting in the mid-1970s when the Singapore-based MFRD had been tasked to pursue the sustainable development of fisheries post-harvest technology, it placed more emphasis in advancing the production of fish and fishery products in the Southeast Asian region following safe and good quality standards. In so-doing, MFRD has adopted three major concepts, namely: maximizing the utilization of fish catch through the development of various fishery products, minimizing wastage by reducing post-harvest losses, and ensuring the safety and quality of the region's fish and fishery products. In the process, MFRD had developed technological approaches to utilize small demersal fish species, most commonly known as "trash fish" as well as small pelagic fish species that are often regarded as of low-economic value, as raw materials for the production of surimi and fish jelly products, which had already become an industry in the Southeast Asian region, and recently, under-utilized freshwater fish species have also been used as raw materials for the production of value-added products. Meanwhile, to minimize wastage of the so-called low-economic value fish, SEAFDEC has been developing the systems for improved handling of catches onboard fishing vessels as well as improving the facilities for onboard and onshore fish processing. Aside from promoting the application of quality and safety assurance systems for the fish processing industry, MFRD also harmonized the analytical methods for detecting and containing various hazardous substances in fish and fishery products, *e.g.* heavy metals, antibiotics and pesticide residues, biotoxins, and identifying the harmful algal bloom species producing biotoxins.

SEAFDEC desires that its efforts in promoting healthy and wholesome aquaculture in the region through AQD and pursuing the sustainable development of fisheries post-harvest technologies by MFRD, would not only help secure the niche of the region's fish and fishery products in the world market but also enhance the marketability of such products. As an offshoot, the flow of foreign exchange into the economies of the Southeast Asian countries would be boosted while the long-term food security in the region could be assured.

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FISH for the PEOPLE is a special publication produced by the Southeast Asian Fisheries Development Center (SEAFDEC) to promote sustainable fisheries for food security in the ASEAN region.

Orchestrating the Southeast Asian Aquaculture towards Sustainability: SEAFDEC Initiative

Chumnarn Pongsri, Felix G. Ayson, Virgilia T. Sulit, Belen O. Acosta, and *Nualanong Tongdee*

Three years after the Philippines became a signatory to the Agreement Establishing the Southeast Asian Fisheries Development Center (SEAFDEC) in January 1968, the Philippine Government submitted a Position Paper during the Fourth Meeting of the SEAFDEC Council in January 1971, formally inviting SEAFDEC to establish a regional aquaculture project in the Philippines. This was anchored on the decision reached during the Third Ministerial Conference for the Economic Development of Southeast Asia in 1968, for SEAFDEC to consider the establishment of a new department to deal with freshwater and brackishwater fish culture, in addition to the already established Research and Training Departments. Subsequently, the Ministerial Conference established a working group of aquaculture experts from the Member Countries to conduct a study on the aquaculture situation in Southeast Asia. Their report which indicated that the new SEAFDEC Department could be established in the Philippines was considered by the Fourth Ministerial Conference for the Economic Development of Southeast Asia in 1969. This led to the series of surveys in the Philippines, conducted by a Survey Mission from the Japanese Overseas Technical Cooperation Agency headed by Dr. Katsuzo Kuronoma, former President of Tokyo University of Fisheries, Japan from 1969 to 1971 to identify the appropriate site of this new Department. Together with counterpart experts from the Philippines, the Survey Mission concluded that the Aquaculture Department would be established in Iloilo Province, Panay Island, Philippines, to undertake aquaculture research in the region, and training of researchers and technicians in aquaculture. Following a conference in September 1972 among representatives from the Philippines and Japan, the Mindanao State University which at that time had already developed the technology for breeding penaeid shrimps, was designated as implementing agency of the Project for the Philippine Government. Although shrimp culture was given priority in the initial project plan, it was also agreed that the new Department could undertake, whenever feasible, the culture of other coastal and brackishwater species, and in a subsequent stage, freshwater fish culture. Based on such recommendations and the commitments of the Governments of Japan and the Philippines to support the operations of the new SEAFDEC Department, the Sixth Meeting of the SEAFDEC Council in July 1973 in Kuala Lumpur, Malaysia agreed to establish the Aquaculture Department in Iloilo, Philippines, adopted the corresponding Plan of Operation and Program of Work, and approved the appointment of Dean Domiciano K. Villaluz as the first Department Chief. True to its word, the Aquaculture Department has since then been pursuing programs on sustainable development and responsible stewardship of aquaculture resources in Southeast Asia through research and promotion of appropriate aquaculture technologies and socio-economic strategies relevant to the sustainability of the aquaculture industry in the region.

Since its establishment in 1973, the Aquaculture Department (AQD) of SEAFDEC has continued to carry out research, technology generation, training, and information dissemination activities on a wide range of aquaculture disciplines, *i.e.* management of broodstock and seed quality improvement, promotion of responsible and environment-friendly aquaculture, disease diagnosis, prevention and control, and aquaculture for stock enhancement of threatened species. These activities cover various aquatic commodities, *e.g.* milkfish, groupers, Asian sea bass, snappers, siganids, pompano, bighead carp, catfish, tilapia, tiger shrimp, other penaeid shrimps, freshwater prawn, mud crab, blue swimming crab, abalone, sea cucumber, seahorse, oysters, mussels, seaweeds, Napoleon wrasse, and others. AQD also promotes good aquaculture practices and effective management of aquatic resources to support rural development and alleviate poverty. Being in the forefront of harnessing the aquaculture potentials in the Southeast Asian region, AQD makes sure that its programs and activities address the requirements and priorities of the ASEAN Member States (AMSs) towards sustainable aquaculture development. Specifically, in carrying out its programs and activities, AQD sets its sights on ensuring that the region's aquaculture operations are technologically feasible, responsibly producing safe and quality aquaculture products, socially and economically viable, and environmentally sound, in accordance with the provisions on aquaculture in the Resolution and Plan of Action that were adopted by the ASEAN Members States in 2001 and its superseding Resolution and Plan of Action adopted in 2011. In the Southeast Asian region, aquaculture is categorized into mariculture, brackishwater culture, and freshwater culture.

Aquaculture Development in Southeast Asia

Although fish farming in Southeast Asia has been considered as an age-old practice, it was only in the early 70s that it became an industry in Southeast Asia when many countries picked up the rudiments of aquaculture operations. Reports have indicated that freshwater aquaculture in Southeast Asia might have started with what is now known as rice-

Bountiful harvest of milkfish in the Philippines

fish culture which is actually an extension of rice farming in paddies and where fish that migrate through canals and refuge are raised to commercial size. Nonetheless, freshwater fish culture could already be considered an industry in many countries in Southeast Asia, *e.g.* Thailand, Cambodia, Myanmar, Lao PDR, Viet Nam, considering that technologies for freshwater fish breeding had already been developed and freshwater fish seeds are available for culture in inland water bodies.

In other countries, such as Indonesia and the Philippines, brackishwater aquaculture had always been practiced for centuries, with milkfish as the main species being cultured. Production of penaeid shrimps had its humble beginnings when early milkfish ponds also yielded shrimps as by-products. Subsequently, shrimp culture developed into an industry when shrimps, especially the tiger shrimp (*Penaeus monodon*) started to command high prices while demand in international markets continued to rise. Meanwhile, mariculture in Southeast Asia could be considered a late bloomer, being introduced to culture other marine aquatic species away from land areas that had become scarce due to land conversion for the sake of development. Nonetheless, records have also shown that the culture of marine species, *e.g.* oysters and seaweeds, is an ancient practice in many regions of the world.

Aquaculture has greatly expanded when scientists established the life cycles of many "culturable" aquatic species that led to the development of fish culture technologies, *i.e.* breeding, feeding and fish health management, among others. Starting with carps, tilapia, bivalves, milkfish, and the luxury item penaeid shrimps as the most common aquaculture produce, the trend changes as new technologies for the culture of other marine species were developed, leading to the production of other aquatic species that serve as source of protein for local fisherfolks and additional foreign exchange earnings for the countries.

Since the start of the commercialization of aquaculture in Southeast Asia in early 70s, cultured fish production has been steadily rising during the first two decades accounting for about 11% of the region's total fisheries production in terms of volume and 23% in terms of value annually. In the second decade starting mid 90s until mid 2000s when aquaculture technologies had been improved and responsible aquaculture was promoted in Southeast Asia, production from aquaculture sharply increased, annually contributing about 31% to the region's total production from fisheries in terms of volume and 44% in terms of value (**Table 1**).

Specifically during the past ten years from 2003 to 2012, the aquaculture sector of the Southeast Asian region annually contributed an average of about 21% to the world's aquaculture production, and 8% to the world's fish production (**Table 2**). While mariculture contributed an average of 42% annually to the region's total aquaculture production, freshwater culture had been following closely at 38% and brackishwater culture at 20% (**Table 3**). The increasing volume of production from mariculture has been brought about by increased production of seaweeds in Indonesia and the Philippines while that of freshwater culture was due to increases in the production of pangas catfish and miscellaneous freshwater fishes by Viet Nam starting in 2010.

Table 1. Trend of fisheries and aquaculture production in Southeast Asia (1974-2012)*: Quantity in 1000 metric tons (MT); Value in 1,000,000 US$

	1974-1978	1979-1983	1984-1988	1989-1993	1994-1998	1999-2003	2004-2008	2009-2012
Total Fisheries Production of Southeast Asian (five-year averages)								
Quantity	6,395.1	7,457.9	8,809.7	11,024.4	14,208.9	17,983.3	24,159.8	33,352.6
Value	2,567.1	4,127.3	4,361.5	5,307.0	8,244.9	11,802.8	19,910.6	39,175.3
Aquaculture Production of Southeast Asia (five-year averages)								
Quantity	483.2	718.5	1,069.2	1,628.0	2,320.2	4,272.6	8,452.9	15,869.5
Value	318.9	771.5	975.2	1,913.1	3,367.6	4,912.6	9,494.1	17,678.7

Sources: SEAFDEC (1980), SEAFDEC (1984), SEAFDEC (1987), SEAFDEC (1992), SEAFDEC (1994), SEAFDEC (1997), SEAFDEC (2002), SEAFDEC (2006), SEAFDEC (2010), SEAFDEC (2014)

* *Five-year averages of aquaculture production from Southeast Asian countries (Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam)*

Seaweed harvest in the Philippines

The major commodities in freshwater culture comprise mainly carps, barbs and other cyprinids, tilapias, catfishes and miscellaneous freshwater fishes, produced by Indonesia, Myanmar, Thailand, and Viet Nam, while penaeid shrimps, *e.g.* tiger shrimp, vannamei shrimp, and other penaeids (**Table 3**) comprised the major commodities produced from brackishwater culture, notably by Indonesia, Philippines, Thailand and Viet Nam. Mariculture has always been dominated by seaweeds produced by Indonesia and the Philippines.

Table 2. Southeast Asia's aquaculture production *vs*. world's total fisheries production (units in million metric tons)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total fisheries production: World*	132.2	134.3	136.4	137.1	140.7	143.1	145.8	148.1	155.7	158.0
Total aquaculture production: World*	41.9	41.9	44.3	47.4	49.9	52.9	55.7	59.0	62.0	66.6
Total fisheries production: Southeast Asia**	20.2	21.1	22.9	24.4	25.2	27.3	28.9	31.4	33.5	39.6
Total aquaculture production: Southeast Asia**	5.4	6.2	7.4	8.4	9.2	11.1	12.4	14.2	15.8	21.2

** Sources: FAO (2004), FAO (2010), FAO (2014)*
*** Sources: SEAFDEC (2005), SEAFDEC (2010), SEAFDEC (2014)*

Table 3. Ten-year trend of the volume of Southeast Asia's aquaculture production* (units in million metric tons)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Volume Total aquaculture production	**5.4**	**6.2**	**7.4**	**8.4**	**9.2**	**11.1**	**12.4**	**14.2**	**15.8**	**21.2**
Mariculture	**2.2**	**2.7**	**3.0**	**3.6**	**3.8**	**4.7**	**5.0**	**5.9**	**7.1**	**8.5**
Seaweeds	1.3	2.0	2.3	2.9	3.1	2.1	4.3	5.3	6.4	7.8
Sea mussels	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2
Blood cockles	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Misc. marine molluscs			0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Others	0.4	0.2	0.1	0.1	0.1	2.1	0.1	0.1	0.3	0.3
Brackishwater culture	**1.2**	**1.5**	**1.9**	**1.9**	**2.1**	**2.1**	**2.7**	**2.5**	**2.6**	**2.7**
Milkfish	0.4	0.5	0.5	0.5	0.5	0.3	0.4	0.7	0.7	0.8
Tiger shrimp	0.4	0.5	0.6	0.4	0.4	0.5	0.4	0.3	0.2	0.2
Vannamei shrimp	0.1					0.8	0.6	0.8	0.7	0.8
Other penaeid shrimps		0.3	0.4	0.6	0.6	0.3	0.6	0.1	0.1	
Misc. marine fishes					0.2		0.6	0.1	0.2	
Gracilaria seaweeds								0.4	0.6	0.8
Others	0.3	0.2	0.4	0.4	0.4	0.2	0.1	0.1	0.1	0.1
Freshwater culture	**2.0**	**2.0**	**2.5**	**2.9**	**3.3**	**4.3**	**4.7**	**5.8**	**6.1**	**10.0**
Cyprinids	0.6	0.6	0.3	0.5	0.4	0.7	0.2	0.9	0.6	3.8
Tilapias	0.4	0.4	0.5	0.5	0.6	0.6	0.6	1.8	1.1	1.2
Catfishes	0.3	0.3	0.7	0.8		0.2	0.2	0.5	0.6	0.6
Pangas catfish					1.2	1.5	1.1	0.4	0.3	0.4
Misc. freshwater fishes		0.3	0.9	1.0	0.9	0.6	2.0	0.9	2.9	2.9
Roho labeo						0.4		1.0	0.6	0.6
Others	0.7	0.4	0.1	0.1	0.2	0.3	0.6	0.3		0.5

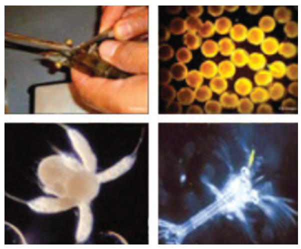
**Sources: SEAFDEC (2005), SEAFDEC (2010), SEAFDEC (2014)*

Table 4. Ten-year trend of the value of Southeast Asia's aquaculture production* (units in million US$)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Value of total aquaculture production	**5.9**	**7.2**	**7.7**	**7.2**	**12.8**	**14.0**	**16.0**	**13.4**	**19.7**	**21.7**
Mariculture	**1.6**	**0.6**	**1.3**	**1.9**	**0.9**	**3.0**	**2.2**	**2.7**	**1.8**	**2.9**
Seaweeds	0.1	0.2	0.3	0.3	0.5	1.3	1.0	1.4	1.2	2.0
Misc. marine molluscs	0.2	0.2	0.7	0.9	0.2	0.2	0.4	1.0	0.2	0.2
Others	1.3	0.2	0.3	0.7	0.2	1.5	0.8	0.3	0.4	0.7
Brackishwater culture	**2.9**	**4.6**	**4.6**	**4.0**	**6.0**	**5.7**	**7.2**	**6.5**	**6.1**	**6.1**
Milkfish	0.4	0.5	0.5	0.5	0.6	0.5	0.5	1.4	1.2	1.3
Tiger shrimp	1.8	2.3	2.2	1.3	2.0	1.4	1.8	1.6	1.2	1.3
Vannamei shrimp	0.3					0.2	1.8	3.0	2.4	3.3
Other penaeid shrimps		1.7	1.7	1.9	1.8	1.7	0.4	0.4	0.4	
Misc. marine fishes				0.1	0.3	0.4	1.9		0.4	
Others	0.4	0.1	0.2	0.2	1.3	1.5	0.8	0.1	0.5	0.2
Freshwater culture	**1.4**	**2.0**	**1.8**	**1.3**	**5.9**	**5.3**	**6.6**	**4.2**	**11.8**	**12.7**
Cyprinids	0.3	0.2	0.2	0.2	0.8	0.5	0.2	0.5	2.2	2.4
Tilapias	0.3	0.4	0.4	0.5	0.5	0.3	0.7	1.1	2.2	2.7
Catfishes	0.2	0.4	0.4	0.3	1.5		0.3		1.4	1.6
Pangas catfish						1.9	1.6	0.3	1.1	1.3
Misc. freshwater fishes		0.6	0.6	0.1	1.9	2.2	3.1	1.6	4.6	2.5
Roho labeo						0.3	0.4	0.5	0.2	1.8
Others	0.6	0.4	0.2	0.2	1.2	0.1	0.3	0.2	0.1	0.4

**Sources: SEAFDEC (2005), SEAFDEC (2010), SEAFDEC (2014)*

In terms of the value of the region's aquaculture production during the last ten years (2003-2012), the highest contribution came from brackishwater culture at an annual average of 43%, closely followed by freshwater culture at 42%, and mariculture at 15% (**Table 4**). The increasing value of production from brackishwater culture had been brought about by increases in the value of penaeid shrimps, more particularly the vannamei shrimp, while that of freshwater culture was due to the increasing value of tilapias and miscellaneous freshwater fishes and the *pangas* catfish.



Role of SEAFDEC in the Sustainable Development of Aquaculture in Southeast Asia

Development of the aquaculture sector in Southeast Asia has always been in accord with the progress made by the SEAFDEC Aquaculture Department (AQD) in terms of aquaculture technology generation (SEAFDEC Aquaculture Department, 2013). AQD's R&D in shrimp culture, notably the giant tiger shrimp (*Penaeus monodon*), started in early 1970s immediately after its establishment and is therefore as old as AQD itself. As AQD continued to reap successes in its innovative works on the biology, broodstock management and maturation of the tiger shrimp, its outputs had been disseminated and were subsequently picked up by the

countries contributing largely to the development of shrimp breeding in the region.

Results of AQD's studies on shrimp nutrition, health management and grow-out culture have also been adapted by the countries for their advancing shrimp industry. As a result, Southeast Asia's shrimp aquaculture sub-sector is now one of the highest producers of shrimps for the world market, contributing about 17% to the world's total production from farmed crustaceans (FAO, 2014). In the Southeast Asian scene, shrimp aquaculture in 2012 accounted for about 5% of the total aquaculture production volume and about 21% in terms of value (SEAFDEC, 2014).

AQD's achievements in milkfish aquaculture started during the late 70s with the closing of the life cycle of milkfish (*Chanos chanos* Forsskal). The pioneering studies of AQD on reproduction, larval biology and nutritional requirements of milkfish led to the captive breeding and production of high quality milkfish fry. Hatcheries now supply most of the fry and fingerling requirements of the milkfish industry which dramatically expanded from traditional brackishwater pond culture to pens and cages in freshwater bodies and coastal waters. Such feat has served as model for improved culture technologies which could be adapted for the culture of various commodities in most countries of the region.

The common practice of using wild crablets in mud crab aquaculture, especially in the Philippines which has a long history of mud crab farming, has led to the dwindling mud crab resources. In order to address such concern, AQD developed the technologies for mud crab hatchery, nursery and farming focusing on *Scylla serrata*, which are now being adapted in other Southeast Asian countries.

The success of AQD in completing the life cycle of abalone in captivity has led to the promotion of the responsible culture of the donkey's ear abalone (*Haliotis asinina*). Technologies developed by AQD for mass seed production, feed formulations and feeding management for juveniles, grow-out culture in floating cages, sea ranching and stock enhancement, had been pilot-tested with the private sector. These technologies are now being disseminated through training courses on abalone offered annually by AQD.

After the establishment of its Binangonan Freshwater Station near Laguna Lake in northern Philippines in 1976, AQD embarked on freshwater aquaculture R&D focusing on the Nile and red tilapias, bighead carp, native clariid catfish, and freshwater prawn. Since then, breeding and seed production techniques, feed formulations, farm-based genetic selection schemes have been developed, and disseminated to aquafarmers in the region through AQD's training and information activities. AQD is also pursuing a research on indigenous freshwater fishes like the silver therapon and climbing perch for sustainable aquaculture and biodiversity conservation.

The high demand for live reef food fish in the world market due to the health benefits of eating fish has led to brisk expansion of live reef food fish trade (LRFFT), especially in Asia. In response to concern over possible over-exploitation of the reef fishes, AQD developed the technologies for captive breeding, hatchery and fry production, farming systems, and feed development and management of high-value marine fish species such as rabbitfish, pompano, mangrove red snapper, sea bass, and groupers. The full-cycle aquaculture of these species is expected to help ease the pressure on wild fisheries and at the same time support the sustainability of LRFFT for the benefit of small-scale fishers and fish farmers in the Southeast Asian region.

In an effort to sustain production of seaweeds as top export commodity of the Southeast Asian region, AQD mobilized its expertise to maintain the competitiveness of the region's seaweed industry in the world market. Focus was therefore placed in improving the farming technology of *Kappaphycus* spp. and *Gracilaria* spp., and developing new and better-performing (in terms of growth and resistance to ice-ice disease) strains of *Kappaphycus* spp. Farming of these commercially important red seaweeds could provide alternative livelihood to poor fishers and coastal dwellers in the Southeast Asian countries.

In the early 2000s, AQD initiated the genetic improvement of the giant freshwater prawn *Macrobrachium rosenbergii*




with the cooperation of research institutions in Thailand and Indonesia. As a result, seed production studies have improved the survival in the hatchery by up to 70% while AQD was able to successfully develop lake-based cage culture technology, now being transferred to stakeholders in the region through AQD's training and information dissemination activities.

After AQD developed the hanging raft method for mussel and oyster culture, it has been promoted to fish farmers because such technique is not only environment-friendly but also results in better growth and gives higher financial returns. For *Placuna placenta*, AQD developed the sustainable broodstock management and spawning techniques, and juvenile production in hatcheries with the objective of replenishing depleted natural stocks. Although locally adopted, results of AQD's initiative in the restocking of this shell along the Panay Gulf in western Philippines starting in the late 90s resulted in recruitment and bountiful harvest ten years later.

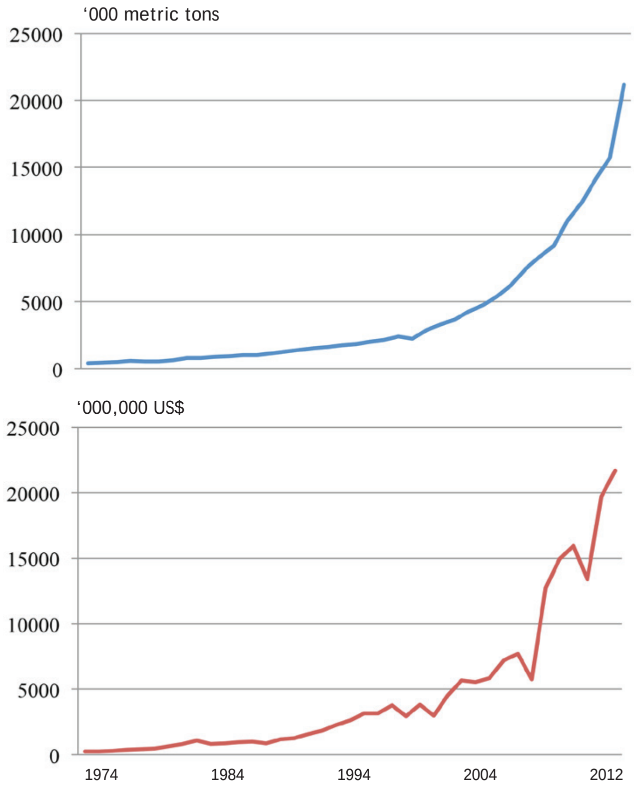
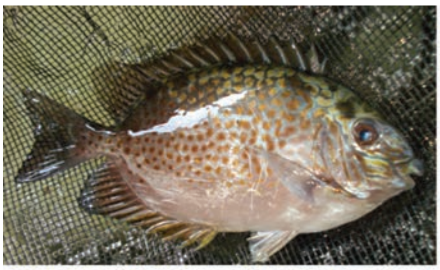


Fig. 1. Trend of aquaculture production of Southeast Asia (1974-2012): volume (*above*) and value (*below*)

The efforts of AQD in its R&D had paid off as aquaculture production continued to increase not only in terms of production but also in terms of value, as shown in **Table 1** and **Fig. 1**. More specifically, starting in the early 2000s, production from aquaculture attained drastic increases at an annual average rate of 14%. It was also during this period that SEAFDEC regionalized the FAO Code of Conduct for Responsible Fisheries (CCRF): Responsible Aquaculture. Thus, the Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Aquaculture (SEAFDEC, 2005a), which has since then been promoted in the Southeast Asian region, ensures that the Southeast Asian





countries' aquaculture operations are done in responsible and environment-friendly manner.

Way Forward

While SEAFDEC/AQD has continued to prosper in its R&D efforts over the past 42 years based on its mandates, it is also setting its sights in supporting the growth of aquaculture sector in the region through development and transfer of responsible and sustainable aquaculture technologies and practices and strengthening the capacities of the aquaculture sector to enhance technology transfer. To steer AQD towards achieving these long-term objectives and a vision of becoming a global leader in the generation and transfer of appropriate and sustainable tropical aquaculture technologies for food security and holistic human development, AQD would continue to conduct activities that would address these objectives: (i) generate, verify and promote technologies to ensure sustainable production of quality seedstock for aquaculture and stock enhancement; (ii) improve aquaculture production through innovations in nutrition and feeding and fish health management in aquaculture and in maintaining the environmental integrity of aquaculture; (iii) develop environment friendly-based aquaculture technologies by integrating environmental factors with the overall effort of AQD in promoting responsible aquaculture; (iv) identify research approaches that could help the region's aquaculture sector adapt to the impacts of climate change; and (v) develop and implement social and economic strategies in aquaculture and resource enhancement to secure food and incomes of the region's populace as well as alleviate the rural communities through stakeholder collaboration.

Now that AQD is entering the threshold of its golden decade, it would place more emphasis on addressing the above-mentioned objectives and other emerging needs and priorities of the Southeast Asian countries. This will be done through the development and accelerated transfer of appropriate technologies anchored on solid R&D and in accordance with its mandate. Overall, these strategies are expected to dovetail towards attaining the sustainability of the aquaculture industry in Southeast Asia.

References

FAO. 2014. The State of the World Fisheries and Aquaculture: Opportunities and Challenges. Food and Agriculture Organization of the United Nations, Rome, Italy; 223 p

SEAFDEC Aquaculture Department. 2013. Reducing Rural Poverty and Improving Lives through Sustainable Aquaculture: AQD's 40-year Saga of Mustering Strength and Expertise for Technology Development. ***In***: Fish for the People, Volume 11, Number 2 (2013). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 42-47

SEAFDEC. 1980. Fishery Statistical Bulletin for South China Sea Area 1978. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 200 p

SEAFDEC. 1984. Fishery Statistical Bulletin for South China Sea Area 1982. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 268 p

SEAFDEC. 1987. Fishery Statistical Bulletin for South China Sea Area 1985. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 178 p

SEAFDEC. 1992. Fishery Statistical Bulletin for South China Sea Area 1989. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 169 p

SEAFDEC. 1994. Fishery Statistical Bulletin for South China Sea Area 1992. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 159 p

SEAFDEC. 1997. Fishery Statistical Bulletin for South China Sea Area 1994. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 159 p

SEAFDEC. 2002. Fishery Statistical Bulletin for South China Sea Area 1998. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 142 p

SEAFDEC. 2005. Fishery Statistical Bulletin for the South China Sea Area 1999-2001. Southeast Asian Fisheries Development Center, Bangkok, Thailand; III-183 p

SEAFDEC. 2005a. Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Aquaculture. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines; 42 p

SEAFDEC. 2010. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2012. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

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The Saga of Fisheries Post-harvest Technology in Southeast Asia: from *Fish Balls* to *Fish Bah Kwa*

Chumnarn Pongsri, Yeap Soon Eong, Virgilia T. Sulit, and *Nualanong Tongdee*

When the Singapore-based SEAFDEC Marine Fisheries Research Department (MFRD) became operational in 1969, it was tasked to undertake R&D on fishing ground development, fishery resources investigation, oceanography, handling and preservation of fish onboard fishing vessels at sea, and improvement of fishing equipment. After the loss of its research vessel, the M.V. Changi in April 1974, MFRD was obliged to shift its emphasis to fisheries post-harvest technology. The refocusing of its programs was timely considering that landings of trash fish in the region during that decade, had increased in view of the expansion of trawl fishing activities, and this necessitated the conduct of activities for more efficient utilization of the catch for human consumption while keeping the quality of the fish. In addition, demand for the region's traditional fish products such as dried, salted, smoked, and fermented fish had also increased, making it imperative to improve the region's traditional fish products with adequate quality control based on organized quality standards for the safety of consumers. Thus began the new fisheries post-harvest technology program of MFRD, with emphasis on fish utilization and preservation, and quality upgrading of traditional fish products. Consequently, the amended Plan of Operation and Program of Work of MFRD which was adopted by the SEAFDEC Council of Directors provided that MFRD would carry out R&D on post-harvest technology directed towards maximum utilization of available fish resources and development of fish products from under-utilized fish resources with a view to reducing wastage; addressing the problems related to handling, preservation and quality control of fish and fishery products; and transferring of the developed post-harvest technologies to the Southeast Asian region through capacity building.

After being equipped with its new mandate, the SEAFDEC Marine Fisheries Research Department (MFRD) initiated in 1978 an investigation of the various means of utilizing available fish resources, mainly small demersal fishes as trawl by-catch, also known as "trash fish". At the start, MFRD made use of these low-market value fishes as new raw materials and improved the production of popular traditional comminuted products for human consumption, *e.g.* fish balls, fish cakes, especially in terms of safety and quality. Later on, these were used as raw materials for the production of surimi. With continued improvements in the technological approaches, MFRD was able to establish the methods of producing frozen surimi or fish jelly products which have been picked up by many Southeast Asian countries, leading to the dramatic growth of the surimi industry in Southeast Asia.

Surimi or frozen minced fish meat or fish paste or fish jelly has always been an integral part of the Asian cuisine, with Japan reported to have registered the highest volume of annual consumption at about 0.5 million metric tons (MT) and at the same time also one of the world's highest producers of surimi. In Southeast Asia, the key players in surimi production are Viet Nam, Thailand, Myanmar, and Malaysia. Together with Japan and other Asian countries, it is believed that production volumes of surimi could be more than 1.5 million MT annually.

Surimi production in Southeast Asia in the early 1970s was almost nil and limited only to the production of traditional comminuted fish products — fish balls and fish cakes. With the advent of improved fisheries post-harvest technology being disseminated to the region through the capacity building activities of MFRD, surimi industry in Southeast Asia has significantly prospered. Thus, surimi has since then been used to produce quality fish balls, fish cakes, fish sausage, fish burgers, *chikuwa*, imitation crab stick, among others, not only for domestic consumption but also for export.

Surimi Top-producing Countries in Southeast Asia

Demersal fishes belonging to five families —Synodontidae, Priacanthidae, Sciaenidae, Nemipteridae, and Mullidae — have been used as raw materials for the production of surimi in the Southeast Asian region. The region's production of these fish species had been increasing from the mid-1970s to mid-2000s with Indonesia, Thailand, Malaysia, and the Philippines emerging as top producers (Siriporn *et al.*, 2007). In recent years however, the region's production of these fish species had exhibited decreasing trend, especially from Thailand since its demersal fishery resources had been declining. After 2005, production of such fishes had further dwindled as shown in **Table 1**, evoking certain doubts on the capability of these fishery resources to continue contributing to the sustained production of surimi in the Southeast Asian region. In fact, the Vietnamese Association of Seafood Exporters and Producers reported on 29 April 2014 that the global surimi production in 2013 decreased by about 8% from 2012 production due to the decreased surimi production in Southeast Asia brought about by low supply of raw materials.

Notwithstanding the possibility that production of the fish species commonly used for surimi production could still improve with increased production from Myanmar and

Table 1. Total production of fish species used as raw materials for surimi by five countries in 2006-2012*: Indonesia, Malaysia, Myanmar (only for 2010), Philippines, Thailand (in metric tons (MT))

	2006	2007	2008	2009	2010	2011	2012
Synodontidae	101,149	108,880	77,324	82,308	80,777	82,531	103,110
Priacanthidae	136,835	131,754	66,300	72,102	94,812	91,422	98,725
Sciaenidae	133,511	132,872	118,031	121,340	145,298	141,995	142,334
Nemipteridae	296,706	316,308	177,524	174,976	278,806	188,256	157,202
Mullidae	85,694	85,432	79,604	107,673	187,735	123,590	132,705
Total**	**753,895**	**775,246**	**518,783**	**558,399**	****787,428**	**627,824**	**634,076**

* *Production from mid-1970s to mid-2000s was reported in Siriporn* et al. *(2007)*
** *Includes reported production of Myanmar for Sciaenidae, Nemipteridae, and Mullidae for 2010*
Sources: SEAFDEC (2009; 2010; 2010a; 2011; 2012; 2014)

marine fisheries production of Viet Nam could be classified according to species specifying actual production of raw materials for surimi, MFRD launched an intensified program on the maximum utilization of the fishery resources. The program had two-pronged objectives — minimizing pressure on capture fisheries considering that the level of harvest in capture fisheries is not likely to increase significantly, and ensuring that most of fish catch is directed to human consumption thus mitigating possible shortage in food supply.

Nevertheless, the Southeast Asian region continues to supply the world market with surimi. Records have shown that in 2012, Viet Nam emerged as one of the world's top three producers of surimi. The value of the country's surimi export was reported in 2012 to be US$275 million increasing by about 36% from that of 2011. As of 2012, there were 19 companies producing surimi in the country. Thailand is also among the world's top producers of surimi. Since 2005, the country has been producing surimi at an annual average of 150,000 MT (Somboon *et al*., 2009) from 21 companies specializing in surimi production.

Starting in 2005, Myanmar has been producing surimi at an annual average of 12,000 MT/year from 5 companies, and Indonesia has been exporting surimi at 8,000 MT/year produced by the country's 8 companies engaged in surimi production. Meanwhile, Malaysia had 6 companies producing a total of 100,000 MT of surimi in 2005-2006 (Siriporn *et al*., 2007; Somboon *et al*., 2009). There is still a great chance that surimi production in the Southeast Asian countries could increase in the next decades, despite slow increase in the trend of production of marine fish species as raw materials as could be gleaned from **Table 1**. This is because aside from the efforts of many Southeast Asian countries to promote sustainable management of the fisheries, many under-utilized freshwater fishes have also been tried as raw materials for producing surimi after the mechanisms of gel-formation and their gel-forming properties had been clarified and established by MFRD. Moreover, technological advancements in surimi production are being picked up rapidly and adapted by the countries considering the high marketability of fish jelly products for the manufacture of imitation crab sticks, lobster, scallops, clams, shrimps, and other seafood which are highly in demand not only in Japan but also in the EU and USA, making surimi an international commodity. Nevertheless, there is a need to continue improving the fisheries post-harvest technologies adopted in the region to make sure that the region's fishery products including surimi, could compete with those of the other regions in the world.

Role of SEAFDEC in the Improved Fisheries Post-harvest Technology in Southeast Asia

In fulfilling the objective of food security and socio-economic stability in the Southeast Asian region, SEAFDEC deemed it necessary to improve fisheries post-harvest technologies to ensure that the region's fish and fishery products are of good quality and safe not only for export but also for domestic consumption. Besides, SEAFDEC also recognizes that it is very crucial for the Southeast Asian region to enhance the promotion of sustainable fisheries post-harvest technologies in order to secure the niche of the region's fish and fishery products in the world market, as this in turn would largely create great impact on the region's economies. Thus, began the saga of fisheries post-harvest technology development in Southeast Asia.

It is along the premise of securing the niche of the region's fish and fishery products in the world market while ensuring food security in the Southeast Asian region that SEAFDEC/MFRD in collaboration with the Agri-Food & Veterinary Authority (AVA) of Singapore through its Post-Harvest Technology Centre (PHTC) embarked on projects that aim to intensify the development of fisheries post-harvest technologies in Southeast Asia. Specifically, such projects seek to optimize the utilization of catch and reduce post-harvest losses, improve quality of traditional fish products and promote rational utilization of by-products through responsible processing, and institute measures to comply with international safety requirements. As soon as appropriate technologies have been developed by MFRD, these were immediately transferred to the ASEAN Member

States (AMSs), through capacity building with funding support provided by the Japanese Trust Fund. The capacity building scheme advanced by MFRD includes institutional enhancement and human resource development, as well as standardization of post-harvest procedures and analytical methodologies for the AMSs (Yeap and Chow, 2011). As a result, the fish processing industry in the whole Southeast Asian region had immensely improved leading to the upswing of sustainable processing efforts in the region including increased production of surimi.

In 2001 however, a deep concern was expressed over the level of harvest in marine capture fisheries which had not been significantly increasing that could affect the socio-economic condition of relevant stakeholders. In order to address such concern and ensure that maximum benefits could still be obtained by the stakeholders while more fish products would go for human consumption, it was a general consensus in the region to maximize the value of existing fish catch and at the same time, reduce post-harvest losses. Against this backdrop, the Ministers from the AMSs responsible for fisheries adopted the First ASEAN Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium: Fish for the People in November 2001 in Thailand.

Specifically for the region's fish and fishery products, the 2001 Resolution provided that "*maximum utilization of catch including the reduction of discards and post-harvest losses should be promoted to increase fish supply and improve economic returns*"; and that "*post-harvest technologies should be improved to ensure fish quality assurance and safety management systems which are appropriate for small- and medium-sized enterprises in the region, taking into account the importance of traditional fish products and food safety requirements*". Such provisions had fired up the enthusiasm of the researchers from MFRD to intensify the sustainable development of fisheries post-harvest technologies that would ensure the sustainable utilization of fish catch.

Moreover, SEAFDEC also acknowledged the need for the region to enhance its capability in food safety and quality assurance of fish and fishery products to be able to conform to international requirements such as the FAO Code of Conduct for Responsible Fisheries (CCRF) adopted in 1995. The CCRF provides the necessary framework for national and international efforts to ensure sustainable exploitation of aquatic living resources and fish trade in harmony with the environment. In order to facilitate its implementation at national level, SEAFDEC embarked on a project to regionalize the CCRF by examining, clarifying and elaborating the generic provisions, and finally establishing a set of regional guidelines taking into account the regional specificities of fisheries in Southeast Asia. Thus, the Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Post-harvest Practices and Trade (SEAFDEC, 2005) had been developed and promoted in the Southeast Asian region to assist the AMSs in implementing the CCRF, specifically those provisions that pertain to fisheries post-harvest practices and trade.

As significant improvements in the utilization of fish for human consumption continue to take shape in the region, the Ministers from the AMSs responsible for fisheries considered it imperative to "*respond to the challenges of the changing environment and the emerging issues including climate change and the growing gap between the increased demand for fish and fishery products and ASEAN's ability to supply these products in a sustainable manner, and taking into account the imperative to minimize the impacts caused by the increasing pressures on fisheries and globalization of trade*", among others. In this connection, the Ministers adopted the superseding Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 (SEAFDEC, 2011a) during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" organized in Thailand in June 2011.

The 2011 Resolution relevant to fisheries post-harvest stipulates that "*the utilization of catch from water to market should be optimized by reducing post-harvest losses and wastes to increase fish supply and improve economic returns through promotion of appropriate technologies and facilities along the supply chain, and that technologies and facilities should be improved to ensure fish quality assurance and safety management systems, taking account the importance of traditional fishery products and food security requirements, and the development of fishery products should be promoted as an alternative supplementary livelihoods for fisheries communities*". These frameworks have served as guide for MFRD to sustain its activities on value-adding of fish catch for human consumption.

Optimum utilization of fishery resources and minimum wastage of fishery resources

Although in Southeast Asia most of fish catch is actually utilized, in most cases the high-value catch goes mainly for human consumption while the low-value fishes are turned into products for non-human consumption, *e.g.* fish meal for animal feeds. Meanwhile, on board fishing vessels the high-value of the catch could be diminished to low-value due to poor handling onboard giving less benefit to the fishers. It is in this aspect that improvements of techniques in fish handling onboard had been undertaken by SEAFDEC in order that the quality of catch from fishing grounds to the ports is maintained. Promoted in the region by MFRD, such initiatives resulted in improvements of on-shore fish handling and transport as well as advancements in storage and transport facilities.

Furthermore, MFRD also works on the optimum utilization of fish catch in order that fishers and other relevant stakeholders get the best economic benefit from their catch while the supply of quality and safe fish and fishery products for human consumption could be increased contributing to the food security of peoples in the region. From the technological advancements attained by MFRD, many new fishery products have been developed by the Southeast Asian countries not only for the domestic market but also for export. As a matter of fact, products such as fish balls, fish cakes, imitation crab sticks, imitation shrimps, breaded squid rings, breaded fish or shrimp, fish crackers, fish skins, and the like, could now be seen in local supermarkets' shelves, especially in urban centers of many Southeast Asian countries.

Nevertheless, the concern on responsible utilization of low-value fish catch still continues to loom over the region as reports seem to suggest that more low-value marine fishes have been diverted away from human consumption to give way to the manufacture of high-demand fish meal for animal feeds. MFRD therefore intensified its efforts in ensuring that quality value-added products could also be derived from low-value and under-utilized freshwater fishes to sustain the economic benefit that could be obtained by fishers and relevant stakeholders. Following the prescribed safety and quality standards for fishery products, quality value-added products had been produced from such freshwater species as the featherback (*Notopterus* spp.), snakehead (*Channa micropeltes*), moonlight gourami (*Trichogaster microlepis*), and soldier river barb (*Cyclocheilichthys enoplos*). More particularly, the minced meat of the featherback and snakehead fish has been used to produce the value-added product fish *bah kwa*, and that of the soldier river barb has been used to produce the value-added fish snack, fish *murukku*.

With the main objective of improving livelihoods in inland fishing communities, the technologies developed by MFRD on sustainable processing and value-adding of freshwater fishes have been extended to the ASEAN countries through the initiative of the Government of Singapore. Thus, the PHTC of the country's AVA, as the Collaborating Center for MFRD Programmes carried out a three-year project aimed at promoting the optimum utilization of indigenous freshwater species through the development of value-added products, and upgrading the processing and packaging technology for freshwater fish products for commercialization. Through capacity building, the participating countries, namely: Indonesia, Lao PDR, Myanmar, and Viet Nam were able to undertake value-added product development and processing trials using indigenous freshwater fishes. After the project implementation, a processing handbook on *Utilization of Freshwater Fish for Value-added Products* which contains descriptions of freshwater fisheries in the participating countries, freshwater species used in processing, value-added products developed, processing steps and procedures, and shelf-life studies, was published and disseminated to the Southeast Asian countries.

In another development and guided by the Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2010 which stipulates the need to "*introduce and provide support for the development and application of technologies that optimize the utilization of catches, reduce post-harvest losses, wastes and discards in commercial and small-scale fisheries and processing operations*, …", MFRD embarked on activities that were aimed at turning fish trimmings and fish processing by-products into fishery products.

Considering that the Southeast Asian region is a major producer and exporter of tuna in fresh, frozen, chilled or canned forms, some amounts of trimmings and other by-products that are considered as discards could be generated during the processing. Thus, MFRD had been developing value-added products for human consumption from tuna trimmings (Yeap and Chow, 2011) such as breaded and battered tuna products for the production of tuna burger and tuna loaf as well as tuna sausage and tuna pico (small chunks and chips). The technology had been easily picked up by the Southeast Asian countries resulting in the development of value-added products from by-products of their respective fish processing industries.

Quality improvement of traditional fish products

In the Southeast Asian region, traditional fish products — fish sauce and cured fish such as sun-dried, salted and dried, steamed or boiled, fermented, and the like — are major source of micronutrients and animal protein of the populace. Many reports have indicated that 30-45% of fish landed in many Southeast Asian countries are converted into traditional fish products as important means of preserving fish when storage facilities for fresh fish are inadequate. Usually consumed by low-income members of the society, traditional fish products are mostly produced in backyards using low-level technology but such initiative has always served as source of income and rural livelihoods in many fishing communities. In the marketing system however, products from backyard processing could not easily compete with those produced from modern processing industry, especially in terms of quality and quantity, undermining the socio-economic advantage that could be derived by the backyard fish processing industry.

Nonetheless, the traditional fish processing industry has been constrained not only in terms of insufficiency of raw materials but also the low quality of the raw materials, outdated processing and preservation technologies, packaging that remains unappealing to consumers, and marketing practices that seem unreasonable. The latter of which is influenced by the existing pricing structure that dictates low prices for traditional fish products, especially those produced by the backyard fish processing industry. The immediate consequence is the inability and unwillingness of producers not only in improving the quality and safety of their products but also in enhancing their processing operations. Thus, SEAFDEC deemed it necessary to address such concerns and come up with strategies to improve the quality, marketing and trade of traditional fish products from the region. Towards this end, MFRD heeded the call of the AMSs which was specified in the Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020, that "*production of and preserving the diversity of traditional fish products should be promoted by assisting producers to secure stable supplies of quality raw materials, meet food safety requirements and to improve product identity, nutritive value and marketing*". With such provision, MFRD had advocated through its human resource development activities, the development of HACCP (Hazard Analysis and Critical Control Point) plans for traditional fishery products in the AMSs and improvement of the respective countries' local processing industries. Furthermore, MFRD also promoted the mechanization of the processing industry as well as automation of the production line to increase productivity. Thus, through the efforts of MFRD, the region's commonly-used fish processing equipment had not only been modified to suit the capability of the countries but also ensuring that the performance and efficiency of the equipment are maintained.

Measures for Fishery Products from the AMSs to Comply with International Safety Requirements

Traditionally, fish products from the AMSs are generally bound for domestic consumption and largely manufactured by small and medium enterprises, and to a certain extent in backyard processing industries. However, some countries have the potentials to export their fishery products to developed countries such as Japan, the EU and USA. Nonetheless, most processors of traditional fish products in Southeast Asia make use of fish by-catch or low-value fish as raw materials, making production not only seasonal but also to some extent, are of low-quality (Yeap *et al*., 2007). In addition, processors are not well-educated, have inadequate knowledge in preservation and processing techniques, and little access to skills development and information on food hygiene. These factors contribute to the difficulty in complying with safety and quality standards and requirements of fishery products traded in the world market. Moreover, many countries in the region have not yet established the necessary regulations and standards on quality, safety and hygiene for fishery products that meet the requirements of the domestic as well as foreign markets. Along this argument, AMSs explicitly expressed in the Resolution on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 the need to "*improve technologies and facilities to ensure fish quality assurance and safety management systems, taking into account the importance of traditional fishery products and food security requirements, and promote the development of fishery products as an alternative supplementary livelihood for fisheries communities*".

All the while however, MFRD had been addressing such concern through its projects and activities that aim to develop appropriate guidelines in food safety measures such as good manufacturing practices (GMP) and standard sanitation operating procedure (SSOP). MFRD also provided assistance to small and medium enterprises (SMEs) in implementing the said food safety measures. Specifically, the project of MFRD on Quality Assurance Systems for Small- and Medium-sized Fish Processing Establishments developed the necessary quality assurance systems for the SMEs that incorporate GMP/SSOP programs as first step towards the implementation of HACCP systems and eventually helped the SMEs meet safety and quality assurance requirements. Manuals on GMP/SSOP and corresponding guidelines were produced by MFRD and distributed to the AMSs to assist the countries in the conduct of their respective national training programs, which could eventually facilitate compliance of the Southeast Asian countries with international standards for fishery products.

Way Forward

The Codex Alimentarius: Code of Conduct for Fish and Fishery Products provides the specific requirements and techniques to preserve the nutritional quality of fish and fishery products, as well as extend the shelf-life, minimize the activity of spoilage bacteria and avoid losses caused by poor handling (WHO and FAO, 2009). As reported by FAO (2012), fish for direct human consumption marketed as live, fresh or chilled constitutes about 47% of total fish catch while frozen fish constitutes about 29%, and prepared or preserved and cured fish about 24% of total catch. The preservation and curing methods differ by continent, region and country. In Southeast Asia, a number of prepared and cured products are generated in addition to processed products in the form of surimi which is mainly for export.

In order to continue adding value of the fish catch and producing quality fishery products for sustainable development and food security in the Southeast Asian region, SEAFDEC would enhance the development of fisheries post-harvest technology through the regional programs

Box 1. Requirements and preservation techniques for fish and fishery products prescribed by Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC) develops Standards, Codes of Practice, and Guidelines in the area of food safety and fair practices in trade. The Standards specify the characteristics of food products, while the Codes of Practice identify the procedures that national competent authorities and operators in the food chain need to follow in order to reach those Standards. The Guidelines identify steps that need to be taken to protect consumers' health from certain specific food hazards. Standards, Codes of Practice and Guidelines are continuously updated, and new sections are added as required. Recent work by the CAC has led to: (i) adoption of Standards for live and raw bivalve molluscs and fish sauce; (ii) updating of the Code of Practice for Fish and Fishery Products with sections on live and raw bivalve molluscs and smoked fish; and (iii) adoption of Guidelines on the Application of General Principles of Food Hygiene to the Control of Pathogenic *Vibrio* Species in Seafood.

being carried out by the PHTC of AVA as the Collaborating Center of SEAFDEC to undertake the activities of MFRD. Specifically, the projects and activities of MFRD would cover R&D in fisheries post-harvest technology to include optimizing the utilization of available fisheries resources; developing fishery products from under-utilized resources for the sustainable production of surimi and value-added products such as fish balls, fish cakes, fish sausage, fish burgers, fish *bah kwa*, and fish *murukku*; ensuring seafood safety by monitoring chemical contaminants in fish and fishery products such as heavy metals, antibiotic and pesticide residues, and marine biotoxins; promoting seafood quality assurance for handling and quality preservation, as well as application of HACCP and GMP to fish processing establishments in the region; and instituting traceability systems for aquaculture products. In all these efforts, adherence to Codex Alimentarius would be assured, including the safety standards developed by the Codex Alimentarius Commission as shown in **Box 1** (FAO, 2012).

References

FAO. 2012. The State of World Fisheries and Aquaculture 2012. FAO Fisheries and Aquaculture Department. Food and Agriculture Organization of the United Nations, Rome, Italy; 209 p

Goh Kian Heng and Yeap Soon Eong. 2007. Towards Sustainable Post-harvest Technology Development in the ASEAN. *In*: Fish for the People, Volume 5 Number 2 (2007). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 2-7

SEAFDEC. 2005. Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Post-harvest Practices and Trade. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 58 p

SEAFDEC. 2009. Fishery Statistical Bulletin for the South China Sea Area 2006. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 163 p

SEAFDEC. 2010. Fishery Statistical Bulletin for the South China Sea Area 2007. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 165 p

SEAFDEC. 2010a. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2011. Fishery Statistical Bulletin of Southeast Asia 2009. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 149 p

SEAFDEC. 2011a. Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 23 p

SEAFDEC. 2012. Fishery Statistical Bulletin of Southeast Asia 2010. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 143 p

SEAFDEC. 2013. Fishery Statistical Bulletin of Southeast Asia 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 133 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2013. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

Siriporn Pangsorn, Penchan Laong-manee and Somboon Siriraksophon. 2007. Status of Surimi Industry in Southeast Asia 2007. TD/RES 118. Training Department, Southeast Asian Fisheries Development Center, Samutprakan, Thailand; 28 p

Somboon Siriraksophon, Siriporn Pangsorn and Penchan Laong-manee. 2009. The Surimi Industry in Southeast Asia: Trend and Demand for Raw Materials. ***In***: Fish for the People, Volume 7 Number 2 (2009). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 2-8

WHO and FAO, 2009. Codex Alimentarius: Code of Practice for Fish and Fishery Products (1st Ed). World Health Organization, and Food and Agriculture Organization of the United Nations, Rome, Italy; 156 p

Yeap Soon Eong and Melvin Chow Wing Chung. 2011. Ensuring Quality and Safety of Fish and Fisheries Products through Improved Post-harvest Technologies and Safety Management Systems. ***In***: Fish for the People, Volume 9 Number 2 (2011). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 51-57

Yeap Soon Eong, Ira Hariono and Virgilia T. Sulit. 2007. Assisting ASEAN Fish Processing SMEs Meet Safety and Quality Assurance Requirements. *In*: Fish for the People, Volume 5 Number 2 (2007). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 21-27

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Sustaining Environmental Integrity in the Midst of Intensified Aquaculture Development

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The escalating aquaculture production from Southeast Asia during the past decades seems inevitable notwithstanding its significant contribution to economic growth and guaranteed food security of the countries in the region. Despite its good prospects, the region's aquaculture sector is being confronted with various issues that should be addressed to enable it to develop sustainably and contribute unceasingly to poverty alleviation in the region. Responsible aquaculture has been practiced in the region as means of easing the crisis in capture fisheries; however, this has to be matched with effective approaches that address concerns on the fishery resources that are deteriorating. Resource enhancement of economically important aquatic species has been considered as one of the effective approaches that would help protect and restore the aquatic resource habitats and stocks, the latter connotes stock enhancement. As could be gleaned from the current scenario of fisheries in the Southeast Asian region, the recurring over-exploitation of common natural resources has affected the livelihoods of fishers and coastal communities. The imbalanced extraction of natural aquatic resources and natural recruitment has worsened through the years and if left unabated could result in the extinction of many of the region's endemic aquatic species. It is for such consequences that the Aquaculture Department of the Southeast Asian Fisheries Development Center, while intensifying its efforts in developing sustainable aquaculture, is also promoting resource enhancement as these two approaches are expected to enhance the region's fishery resources and food security in view of their perfect roles in improving the productivity of aquatic stocks and status of the natural habitats. Nonetheless, aquaculture techniques have always been used to facilitate the stock enhancement of commercially important, threatened and endangered aquatic species. The National Oceanic and Atmospheric Administration of the USA defines stock enhancement as "restoration aquaculture" or the release of hatchery-bred juveniles of fish and shellfish to the wild, and considers this approach as a management tool to recover depleted stocks due to overfishing and habitat loss. The Food and Agriculture Organization of the United Nations has demonstrated that stock enhancement is a type of culture-based fisheries since part of the life cycle of certain aquatic species is being controlled in hatcheries before the seeds or juveniles are transplanted or released into open waters — freshwater or brackishwater or marine environments — and allowed to propagate or grow on natural foods until reaching harvestable size.

The Philippine-based Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center (SEAFDEC) is mandated to promote and undertake research on aquaculture relevant and appropriate to the region, encourage human resource development in aquaculture through training and extension, and disseminate and exchange information on aquaculture. In accordance with such mandates, AQD has been carrying out research, technology verification, training and information dissemination on a wide range of aquaculture disciplines, including broodstock management and seed quality improvement; promotion of responsible and environment-friendly aquaculture; diagnosis, prevention and control of aquatic diseases; aquaculture for stock enhancement; and culture of aquatic species under international concern.

The aquaculture commodities covered by AQD include fishes, shrimps, crabs, molluscs, and seaweeds. In addition, AQD also promotes good aquaculture practices and effective management of aquatic resources to support rural development and alleviate poverty. AQD is therefore committed to the sustainable development and the responsible stewardship of aquaculture resources through science-based research and the promotion of appropriate aquaculture technologies and information relevant to Southeast Asia.

Resource Enhancement for Environmental Integrity

Embracing a highly diverse flora and fauna, the Southeast Asian region possesses a wide variety of aquatic species that have been utilized for human food and trade, subjecting such resources to continuous over-exploitation for decades. As a consequence, many species have been threatened or endangered, and as a matter of fact, some species which are of commercial importance to Southeast Asia have been listed or proposed for listing in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Such circumstances have regulated capture, collection, trade and utilization of certain species affecting the livelihoods of fishers and the sustainability of fisheries in Southeast Asia, thus, requiring immediate actions toward replenishment of the CITES-listed species as well as over-exploited species, and securing a wholesome ecosystem to support sustainable fisheries for food security and livelihood in the region. In an effort to address such concerns, AQD with support from the Japanese Trust Fund has embarked on a project aimed at restoring the stock levels of some species listed or proposed to be listed in the CITES Appendices and those economically important species in the Southeast Asian region that had

Box 1. AQD's major programs on sustainable aquaculture development

Quality Seeds for Sustainable Aquaculture

Success in the sustainable production of aquatic species depends primarily on the availability of quality seed stocks as well as on the optimal husbandry techniques. Thus, AQD pursued various studies to determine the optimal conditions and methods for producing quality seed stocks in sufficient quantities, including methods for stock improvement such as domestication, broodstock management, strain evaluation, and selective breeding or genetic improvement of traditional and emerging freshwater and marine species.

- The **Development of Good Quality Broodstock and Implementation of Proper Stock Management Protocols** focuses on monitoring genetic structures of base populations, establishing husbandry techniques, culturing live food, and developing suitable formulated diets for good reproductive performance of various commodities, *e.g.* shrimps (*Penaeus monodon*), milkfish (*Chanos chanos*), tilapia (*Oreochromis niloticus*), donkey's ear abalone (*Haliotis asinina*), oysters (*Crassostrea iredalei*), grouper (*Epinephelus fuscuguttatus*), giant freshwater prawn (*Macrobrachium rosenbergii*), and Napoleon wrasse (*Cheilinus undulatus*).
- **Refinement of Hatchery and Nursery Management Methods** has been continued to improve seed stock quality and production of various commodities, *e.g.* pompano (*Trachinotus blochii*), groupers, sea bass, snapper, milkfish, rabbitfish (*Siganus guttatus*), donkey's ear abalone, oysters, mud crab, seaweeds (*Kappaphycus* spp., *Eucheuma denticulatum*), swimming crab (*Portunus pelagicus*), seahorses (*Hippocampus barbouri*, *H. comes*), silver therapon (*Leiopotherapon plumbeus*), sandfish or sea cucumber (*Holothuria scabra*).
- The **Development of Schemes for Production, Management, Maintenance and Dissemination of Genetically Selected and Improved Stocks** which focuses on selective breeding programs, started with selected crustaceans, *i.e.* mud crab, shrimps and giant freshwater prawn.

Maintaining Environmental Integrity through Responsible Aquaculture

This is intended to address issues on the negative impacts of aquaculture on the environment and define strategies on how these impacts could be minimized. Focusing on developing environment friendly-based aquaculture technologies, this project aims to integrate environmental factors in AQD's research activities and promote responsible aquaculture. Thus, studies have been carried out to assess the impacts of aquaculture on biodiversity, and water and sediment qualities in culture areas and adjacent ecosystems both in marine and freshwater systems; develop and promote efficient and suitable environment-friendly culture systems; and conduct biological and ecological studies on species with potentials for resource enhancement.

- **Assessment of the Impacts of Aquaculture on Biodiversity, and Water and Sediment Qualities** has been continued through regular monitoring of the different stations of AQD using the established monitoring systems for water and substrate quality, *i.e.* at *Igang Marine Station* and surrounding areas, bathymetric profile of the areas and sediment size analyses had been completed while the biodiversity of various ecosystems and near the cage installations had been established; at *Tigbauan Main Station*, sampling of the shore areas around the station had been conducted and publication of a book on the marine biodiversity in Tigbauan, Iloilo initiated; and at *Binangonan Freshwater Station*, a comparison of phytoplankton, zooplankton and fish and other vertebrate diversity in two sites around the station, the East Cove (an aquaculture site) and the West Cove (non-aquaculture site) has been carried out.
- On the **Development and Promotion of Efficient and Suitable Environment-friendly Culture Systems**, experiments were conducted to determine the optimal conditions for the culture of sandfish *H. scabra*.
- **Biological and Ecological Studies on Species with Potentials for Resource Enhancement** had been conducted for species such as the giant clam (*Tridacna gigas*), abalone, mud crab, sea cucumber.

Promoting Healthy and Wholesome Aquaculture

AQD has been promoting the concept of healthy and wholesome aquaculture as a holistic approach to fish disease management as well as development of cost-effective feeds that optimize production of robust and healthy farmed aquatic commodities with the least negative impact on the environment. Thus, AQD has been putting more focus on R&D in fish nutrition and aquatic animal health management to develop the technologies/good practices and ensure a steady and reliable supply of safe and quality fish beneficial to the public, as well as enhance the capacity and affordability of adopting such practices by a wide range of small-scale fish farmers.

Adapting to Climate Change Impacts on Aquaculture

This project aims to identify the accompanying changes in the environment brought about by changing climate that affects the aquaculture sector, prepare the sector to the possible effects that these changes may have on aquaculture operations, minimize and mitigate the adverse impacts of climate change on aquaculture, and ensure continued operation of all aquaculture production systems under changing climatic conditions. Thus, studies have been pursued to generate scientific information on the effects of increasing temperature on the susceptibilities of different stages of important tropical aquaculture species like marine fishes, marine invertebrates such as the abalone (*H. asinina*), mud crabs (*S. serrata*); and the acidic conditions and elevated temperature on corals.

Meeting Social and Economic Challenges in Aquaculture

This project is aimed at developing and implementing social and economic strategies in aquaculture and resource enhancement to secure food and income through stakeholder collaboration.

- **Prioritizing Collaborative R&D in Aquaculture in the Region** has been initiated through studies that enhance understanding of the role of aquaculture in poverty alleviation and in formulating relevant policy recommendations. For freshwater aquaculture, the commodities include the giant freshwater prawn and tilapia, and for brackishwater culture and mariculture, abalone and shrimps.
- **Allocating R&D Resources to Address Emerging Issues** focuses on AQD's efforts to promote eco-friendly aquaculture technologies that could provide socio-economic benefits to stakeholders as well as organizational solidarity and commitment among stakeholders. This includes the potential applications of income-generating but eco-friendly culture technologies such as the integrated multi-trophic aquaculture (IMTA) in milkfish mariculture and socio-economic assessment of highly threatened ecology such as the Napoleon wrasse fishery to complement a study on seed production of this species.

Source: SEAFDEC (2014)

Clockwise from top: sea horses, Napoleon wrasse, mud crab, abalone seeds for release in the wild, sea cucumber, and released abalone

been heavily-exploited, as well as promoting resource enhancement for environmental integrity.

Initially, the species identified by AQD for stock enhancement include sea horses (*Hippocampus* spp.) and Napoleon wrasse (*Cheilinus undulatus*) which had been listed in CITES Appendices, and sea cucumber (*Holothuria scabra*), donkey's ear abalone (*Haliotis asinina*), and mud crabs (*Scylla* spp.). Setting its sight towards a holistic resource enhancement project, AQD establishes seed production technologies for the concerned species taking into account the need to preserve genetic diversity and release procedures that aim to minimize the unintended negative impacts of stock release on the wild populations and the other species. Specifically, release strategies to improve survival of released animals in the wild are being developed by AQD, *i.e.* tagging methods, optimum size-at-release, site selection, conditioning of animals prior to release, and securing shelters (Lebata-Ramos *et al.*, 2015). In order to complement such efforts, socio-economic studies are being carried out as means of identifying the appropriate community-based strategies (Salayo *et al.*, 2015).

Moreover, this AQD project also takes into consideration the environmental capacity since the natural habitats of tropical aquatic life had been rapidly deteriorating due to changing environment brought about by anthropological repercussions and the impacts of climate change. Thus, adaptive measures are being developed by AQD to maintain a healthy environment. This project is therefore expected to establish strategies and guidelines of stock enhancement based on sustainable, responsible and environment-friendly approaches.

In order to bolster the project which focuses on resource enhancement of internationally-threatened and regionally-exploited species, AQD is also undertaking a study that promotes sustainable and region-oriented aquaculture through research and capacity-building initiatives. This study complements AQD's R&D on sustainable aquaculture which comprises five major programs (**Box 1**), namely: Quality Seeds for Sustainable Aquaculture; Promoting Healthy and Wholesome Aquaculture; Maintaining Environmental Integrity through Responsible Aquaculture; Adapting to Climate Change Impacts on Aquaculture; and Meeting Social and Economic Challenges in Aquaculture.

Box 2. Lessons shared by the Southeast Asian countries on sustainable aquaculture development *vis-à-vis* resource enhancement

Aquaculture Development

- The rapid increase in growth of aquaculture in Indonesia had been achieved because of various factors, such as: (i) enhanced coordination efforts from Government to farmers; (ii) provision of strong technical assistance and Government support (*i.e.* Government conducts empowering activities in each province); (iii) active participation and commitment of key players (*e.g.* government, R&D institutions, private sector, and farmers) to work together.
- The seaweed industry in Indonesia is successful in view of the strong technical support being provided by the Government to the farmers through the following key strategies: (i) empowering the people, especially the farmers near the coastline; (ii) multi-stakeholder involvement (*i.e.* government agencies, private sector and farmers work together); (iii) adoption of cluster approach to empower the farmers, and as a result farmers gain access to technology and bank loans (dissemination of technology and provision of credit facility are facilitated through groups or clusters of farmers).
- Success of Viet Nam in catfish (*Pangasius* sp.) production and increased revenues generated had been attained through cooperation with International Trade Centre (joint agency of World Trade Organization and United Nations). Viet Nam organized a benchmarking workshop which enabled the country to harmonize VietGAP with the globalGAP. To ensure that every catfish farmer in the country follows the VietGAP, human resource development is given the highest priority which involves training those involved in the process of production and certification, *e.g.* lecturers, auditors, farmers. In order that small-scale farmers in Viet Nam meet the requirements of importing countries, especially for its two main commodities exported, *i.e.* shrimps and catfish, the capacity of farmers in applying the VietGAP has been enhanced, and farmers have been encouraged to link together and form groups or companies. Through the farmers' groups, farmers could access to technical support (training) and credit facilities provided by the Government.

Stock Enhancement

- Fishes to be stocked should be properly checked for the presence of any viruses or any disease-causing agents especially if the source is from the hatchery where broodstocks are imported.
- Countries that are promoting stock enhancement or restocking should allocate funds for the assessment of the impacts of such activities to wild populations.

Source: SEAFDEC/AQD (2014)

Box 3. Issues, gaps and opportunities on sustainable aquaculture development *vis-à-vis* resource enhancement

Aquaculture Development

- In order that the poorer sector of the society could benefit from aquaculture, a viable business model that is most applicable to the poor and beneficial to them should be developed. This model should take into consideration the methods and species to be produced (*i.e.* it should be site specific) and the resources available to the poor farmers.
- As means of harnessing its potentials, small-scale aquaculture could be developed more in inland waters rather than in brackishwater. Since many national institutions and agencies are playing important roles in enhancing the capacity of small-scale aquaculture farmers, their involvement in formulating aquaculture development plans and policies should be enhanced.

Stock Enhancement

- Napoleon wrasse is an endangered species in the Philippines, and in order that this resource in Mindanao (*i.e.* ARMM Region – Autonomous Region in Muslim Mindanao comprising the Provinces of Basilan, Lanao del Sur, Maguindanao, Sulu, and Tawi-Tawi) could be protected from further extinction, cooperation of the local government units and interventions (*e.g.* provision of other livelihood options for fishers) should be enhanced to ensure that the local community would protect the spawning aggregations and prevent from harvesting such resource illegally and indiscriminately.
- On AQD's community-based resource enhancement project in Sagay Marine Reserve (Province of Negros Occidental in western-central of the Visayas, Philippines), the community should be well-equipped and ready to manage its aquatic resources, considering that technical support and capacity building have been provided to them for the last eight years. Since an exit strategy is important and overstaying in the community is not effective, the AQD project should come up with benchmark indicators that will help assess the readiness of the community in managing their own aquatic resources.
- Since genetic monitoring appears lacking in most stock enhancement initiatives in the Southeast Asian region, a strategy that would reduce adverse genetic effects or negative impacts of stock release should be established and adopted by the countries in the region. This would address any potential genetic impacts of hatchery-based resource management.
- On the effects or impacts of stock release during stock enhancement, apart from possible genetic contamination, effects on the carrying capacity of the body of water, including competition should also be considered. Hence, there is a need to bring a balance between genetic and non-genetic (ecological) factors.
- Since most of the species selected for stock enhancement are for export, research institutions and agencies should also give priority to species that are low-trophic, low-value to ensure that benefits could also be gained by the poorer sector of the communities.
- Considering the need to look at what would really benefit the community – sea ranching or mainly restocking only, it is important that apart from knowing what species to use for stock enhancement, the purpose should also be defined and based on an appropriate design, the resource enhancement activity that is most fitting to the communities should be determined.

Sustainable Aquaculture and Resource Enhancement

- The aquaculture sector is most often blamed for some irresponsible practices and loss of biodiversity. Thus, greater conscious efforts must be done in managing aquaculture farms to ensure that biodiversity is conserved.
- Findings from any aquaculture and resource enhancement project should include clear policy recommendations, and in order to reach policy-makers, a clear communication strategy should be included in respective projects' plans and designs. Moreover, the target audience should be well defined and should include decision makers or the 'champions'. The importance of having sufficient budget allocated for technology transfer and identifying the team that would facilitate the communications should also be highlighted in the projects' plans and designs.
- Communication strategy should be accompanied by a scenario-setting to convince policy-makers that for some projects the cost and the benefits arising from the investment could be realized only after several years. NGOs could also be tapped in implementing communication strategies (*e.g.* promoting the importance of mangroves to food security and the need to comply with the laws and regulations on mangrove protection).
- On genetics in aquaculture and stock enhancement, considering that a number of stocks had been under domestication for a long time and in the Philippines alone, many new stocks are candidates for domestication, genetic intervention should be taken into account in order that problems encountered in old domesticated species would not constitute the same problems with the new and upcoming species that would inevitably be subjected to long term domestication.
- On alternative protein source or fish meal substitutes (*e.g.* cowpea meal) in aquafeed formulations, the feasibility and cost-effectiveness, particularly when mass-produced, should be determined, while the overall agricultural impacts and other benefits should be assessed.

Source: SEAFDEC/AQD (2014)

Dissemination of Significant Findings and Sharing of Experiences

Through its project on Sustainable Aquaculture and Resource Enhancement, AQD has continued to assist the Southeast Asian countries in harnessing the full potentials of their resources for aquaculture development while promoting the need to protect and conserve the aquatic environment. In an effort to disseminate the significant findings from the project's activities, AQD with financial support from the Japanese Trust Fund convened the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia in March 2014 in Iloilo City, Philippines. The Workshop was aimed at promoting and augmenting regional initiatives on resource enhancement and sustainable aquaculture practices that would contribute to poverty alleviation, livelihood and food security (Romana-Eguia *et al.*, 2015). The experiences and lessons learned by the Member Countries of SEAFDEC on sustainable aquaculture development and resource enhancement (**Box 2**) were shared during the said Workshop, while various issues as well as gaps and opportunities had also been identified as shown in **Box 3**. The recommendations that were advanced during the Workshop, for the development of sustainable aquaculture and resource enhancement strategies, are summarized in **Table 1**. The status of the activities on sustainable aquaculture development and resource enhancement carried out in the Southeast Asian countries was also reported during the Workshop, where gaps and issues were identified as well as opportunities for further development. A synthesis of such inputs is shown in **Table 2**.

Way Forward

From the results of the project on Resource Enhancement of Internationally-threatened and Over-exploited Aquatic Species in Southeast Asia through Stock Release, AQD would establish the strategies as well as guidelines of stock enhancement based on sustainable, responsible and environment-friendly approaches. AQD would also continue to disseminate the significant findings of the project to the Southeast Asian countries through human resource development activities. As envisioned, environment-friendly resource enhancement of economically important aquatic species would eventually be promoted throughout the Southeast Asian region.

Specifically, considering that the findings from the research activities would be useful to local government unit officers, fisherfolks, researchers and other relevant stakeholders, AQD would continue its effort in bridging the gaps by focusing on the practical levels in order that positive impacts could be generated by the stakeholders that would contribute to the sustainable development of fisheries in the whole Southeast Asian region. While AQD would also continue to promote sustainable aquaculture development through R&D, gaps in this aspect would also be nailed down, to ensure that methods and information available would definitely be useful to relevant stakeholders, especially the aquaculturists, researchers, academicians, and policy-makers. Thus, future activities of AQD would aim to: ensure reliable and sustainable aquaculture production through genetic improvement of commercially important aquatic species and establishment of reliable breeding and mass production techniques for new species for aquaculture; develop environment-friendly feeds from regionally available ingredients; establish management technology of the aquaculture environment taking into account the ecosystem approach to aquaculture; access and analyze the impacts of transfer and adoption of developed sustainable

Table 1. Summary of issues and recommendations for the development of sustainable aquaculture and resource enhancement strategies

Issues	Recommendations
Aquaculture	
• Decreasing prices of aquaculture commodities/increasing cost of production	• Shift to high value species • Add value to low-priced aquaculture commodities (*e.g.* adding omega-3 fatty acid) • Identify and prioritize top five high value species to be focused on during the next 5 years • Conduct value chain analysis for different species • Enhance quality control • Apply competitive enhancement for aquaculture products (*i.e.* quality of products from ASEAN countries for export should be competitive with products from other regions of the world) • Immediately translate/package available technologies which are ready for application and commercialization • Use alternative feed ingredients (*i.e.* alternative to fish meal and highly digestible ingredients) to reduce cost of inputs • Apply efficient feeding management • Harmonize standards in line with ASEAN integration
• Accumulation of inbreeding in domesticated stocks; loss of genetic ability to adapt to climate change	• Collect relevant existing data, monitor pedigree of aquaculture stocks, bring in more geneticists into relevant activities
• Low technology/lack of technology	• Identify specific technologies that need to be addressed
• Lack of public support/established links between academe/research institutions/private sector	• Increase public awareness on the importance of aquaculture
• Need for more community-based aquaculture • Inadequate extension and capacity building programs for small-scale fish farmers	• Empower small-scale/small-holder farmers to enable them to apply GAqP
• Poor seed quality	• Apply genetic traceability of aquaculture stocks and verifiable certification of seed stocks for aquaculture • Use molecular markers for genetic tracing and certification of seeds • Adopt a system in providing certification for genetic tracing and for stock certification • Establish a system for genetic tracing and data bank for information on various stocks • Contribute to global gene bank for valuable species (international collaboration) • Develop regulatory policies to address inbreeding • Provide verifiable information to allow people the option to choose which stocks to use • Apply for ISO certification to address poor seed quality

Table 1. Summary of issues and recommendations for the development of sustainable aquaculture and resource enhancement strategies (Cont'd)

Issues	Recommendations
• Proliferation of invasive species in inland waters • Introduction of exotic species in relation to disease transfer	• Come up with concrete policies/guidelines/regulations on farming of exotic species • Strictly enforce/implement existing policies • Strictly report escapees from farms
• Aquaculture competes with other alternative uses of land and water resources; *e.g.* conversion of areas for aquaculture to other uses	• Apply zoning for marine aquaculture areas
• Aquaculture waste management	• Apply polyculture systems
• Dependence on the use of antibiotics	• Develop appropriate vaccines • Develop disease resistant strains • Discontinue the use of prohibited antibiotics • Strictly implement GAqP • Use immunostimulants and natural antimicrobials • Use probiotics
Resource Enhancement	
• Inadequate understanding of resource enhancement	• Create core group to establish a common definition/description of resource enhancement • Review the existing guidelines and related instruments • Establish protocols
• Insufficient or limited technical knowledge of local government units (LGUs) • Inadequate consultations with stakeholders, academe	• Enhance Information, Education and Communication for local government units, *e.g.* through League of Municipalities in the Philippines, community • Identify all groups doing similar work (*i.e.* on Resource Enhancement) and seek assistance from them (*e.g.* NGOs, universities, research institutions, national agencies)
• No comprehensive planning and project design • Project implementation is too fast	• Conduct community consultations before project implementation • Provide emphasis in community/participatory research • Adopt careful step by step process of implementation (not skipping crucial steps)
• Project duration is not sufficient • Imposition of donor-driven deadlines • Unclear exit strategy of projects	• Promote project transition that must be smooth • Ensure that implementation must be continuous and evolving • Examine the most logical duration of projects (*e.g.* Indonesia coral project with 3 phases, 15-year duration)
• Political term-dependent projects	• Enhance coordination with established institutions (*e.g.* NGOs, stakeholders, academe) • Involve other government agencies (*e.g.* BFAR and DENR for Philippines, Coast Guard) • Include projects in National or Municipal Economic Development Plan
• Incomplete baseline assessment • Absence of monitoring mechanisms	• Conduct at least one year of baseline information gathering before any intervention is made • Compile scientific information and indigenous knowledge (experience) • Facilitate social preparation • Establish more collaboration with agencies in collection of information
• Absence of impact assessment	• Conduct a follow-up on the same sources of information (from baseline: scientific and traditional)
• Data collection problems	• Empower local communities to gather reliable information • Refer to wiki-type information entry as well as logbook entry
• Political 'stunt act' *vs*. science-based	• Provide advance information to local government units and agencies about the benefits of projects before implementation
• Location of projects: use of marine protected areas (MPAs) as release sites	• Ensure careful site selection based on carrying capacity evaluation and complete baseline information
• Alternative livelihood and difficulty of coastal fishers to adapt to changes	• Make sure there is no sudden change from existing norm (*i.e.* types of livelihoods)
• Inadequate sustainable supply of seeds	• Release bigger juveniles instead of larvae • Establish seed production technology
• Seeds (particularly hatchery-bred stocks) and their potential genetic impacts when released in the wild	• Use native/endemic wild broodstocks instead of bred broodstocks
• Seeds as potential carriers of disease-causing agents	• Carry out screening tests • Use disease-free stocks • Conduct quarantine, vaccination, regular monitoring of released animals

Source: Romana-Eguia et al. (2015)

Table 2. Synthesis of the status of sustainable aquaculture development and resource enhancement in Southeast Asia and Japan

Country	Aquaculture/Stock Enhancement Activities	Gaps/Issues	Opportunities for Development
Cambodia	• Focus is on inland fisheries and small-holder freshwater aquaculture (*i.e.* floating cage and pond culture, rice-fish culture, fish culture in small-water bodies)	• Aquaculture is still relatively new (breeding programs have not yet leveled up) • Main constraint is high cost of feeds (commercial pellets are mostly imported) • Aquafarmers lack know-how on rice-fish farming • Inadequate technical assistance and services • Insufficient financial support • Weak communication and social networking	• Abundance of remarkable genetic resource in terms of 500 freshwater species • Many potential aquaculture species
Indonesia	• Main species cultured are: shrimps, groupers, seaweeds, barramundi, pearl oysters, crabs, exotic fishes, milkfish, tilapia, common carp, gourami, and freshwater prawn • Practices: mariculture, brackishwater aquaculture, inland aquaculture (rice-fish culture systems using giant freshwater prawn) • Off-shore farming of barramundi (sea bass) and pompano (with assistance from Norway)	• Need more seeds of barramundi • Problems on fish health and feeds • Inadequate number of extension workers	• Aquaculture development is in the upswing and will continue growing • To ensure that this will grow sustainably, the Government implements aquaculture integration based on the concept of "Blue Economy"
Japan	• Culture of red sea bream, halibut, ayu, Japanese amberjack, rainbow trout, carps, eel, shellfish, sea cucumber, seaweeds and more recently, blue-fin tuna • Improvement of stocks/strains through genetics • Resource enhancement of Chum salmon • Sea ranching of scallops	• Sustainability of eel fishery (population is declining) • Overall production is decreasing (marine aquaculture production was primarily affected by recent earthquake that hit the country) • Instability of business practice in aquaculture due to: low price of aquaculture products caused by overproduction; high cost of production as a result of increase in input costs	• The country has instituted a paradigm shift – from sea ranching to resource enhancement • Research and technological innovations on larvae and fry production • Improvement of culture methods and feed quality • 80 species are targeted for sea ranching and resource enhancement
Lao PDR	• Culture of tilapia in cage, monosex culture • Backyard farming		
Malaysia	• Pond and cage culture of commercial marine fishes, shrimps, red tilapia, hybrid catfish, giant freshwater prawn; culture of bivalves, green mussel, seaweeds	• Low and inconsistent productivity • Occurrence of viral and bacterial diseases in cultured shrimps and freshwater fish species • Increasing production costs due to high input costs • Non-compliance of product quality by entrepreneurs • Decline in exports of ornamental fishes	• Economic Transformation Programme • Enhanced role of aquaculture in food-fish production
Myanmar	• Culture of over 20 species of freshwater species, *e.g.* giant freshwater prawns, carps, tilapias, and catfishes • Paddy-cum-fish farming • Genetic improvement of rohu (*Labeo rohita*) • Farming of marine fishes (*e.g.* sea bass, red snapper, groupers) • Farming of seaweeds	• Marked reduction in production of giant freshwater prawns due to diseases • Stock enhancement is practiced but without monitoring of the released stocks, no recapture of stocks is done although there has been no evidence yet of negative impacts • The country needs stock enhancement in marine fisheries but there are no technical experts available • Need training course on stock enhancement	• Poverty alleviation program in livestock, fisheries and rural development sector • Government has a development plan for sustainable aquaculture and responsible fisheries in order to support food security and generate income for fisheries communities

Table 2. Synthesis of the status of sustainable aquaculture development and resource enhancement in Southeast Asia and Japan (Cont'd)

Country	Aquaculture/Stock Enhancement Activities	Gaps/Issues	Opportunities for Development
Philippines	• Mariculture, brackishwater and freshwater culture of commercially important commodities • Current Government priorities are aquasilviculture and organic aquaculture • Production of high value species • Resource enhancement of internationally threatened species	• Negative impacts of intensive aquaculture • Inconsistent supply of good quality seeds • Disease problems in cultured stocks • Abuse in the use of feeds	• Implementation of Comprehensive National Fisheries Development Plan • Resource enhancement and sustainable fisheries development through countrywide aquasilviculture projects
Singapore	• Coastal farming in floating net cages • Land-based (fish ponds, tanks) farming of tilapia, marble goby, gourami, catfish, snakehead • Ornamental fish farming • Popular marine fishes cultured, *e.g.* sea bass, pompano, groupers, red snapper, mullets and milkfish	• Problems on fish health and farm management • Inconsistent supply of good quality seeds/fish fry • Reliance on prophylactic drugs which may have negative consequences	• Introduction of Good Aquaculture Practices scheme for food fish farming to help improve the standards of the local aquaculture industry and sustainability through responsible management
Thailand	• Marine and coastal aquaculture • Freshwater aquaculture (mostly tilapias, giant freshwater prawns)	• Disease outbreaks in shrimp farms • High cost of aquaculture feeds	• Milkfish as new species for aquaculture • Implementation of shrimp GAP
Viet Nam	• Marine and coastal aquaculture • Freshwater aquaculture • Shrimp and catfish industries are fast developing	• Disease outbreaks (more recent problem is incidence of Early Mortality Syndrome in shrimps) • High cost of aquaculture feeds	• Widespread implementation of Good Aquaculture Practices (VietGAP)

Source: SEAFDEC/AQD (2014)

aquaculture technologies to the fisherfolk in the whole region; and sustain the dissemination and demonstration of developed aquaculture technologies.

References

Lebata-Ramos, M.J.H., E.F. Doyola-Solis, R. Sibonga, J. Sumbing, J.B. Abroguena, A. Santillan and M. Dimzon. 2015. SEAFDEC/AQD Stock Enhancement Initiatives: Release strategies established. Presented during the Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region, Pattaya, Thailand; 27-30 July 2015.

Romana-Eguia, M.R.R., F.D. Parado-Estepa, N.D. Salayo and M.J.H.L. Ramos (eds). 2015. Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia: Challenges in Responsible Production of Aquatic Species. Proceedings of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014 (IWRESA). SEAFDEC/AQD, Tigbauan, Iloilo, Philippines; 330 p

Salayo, N.D., R.J. Castel, D.H. Tormon, R. Barrido and T. Azuma. 2015. Community-based Stock Enhancement of Abalone, *Haliotis asinina*, in Sagay Marine Reserve, Philippines: Achievements, limitations and directions. Presented during the Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region, Pattaya, Thailand; 27-30 July 2015.

SEAFDEC. 2014. SEAFDEC Annual Report 2014. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 80 p

SEAFDEC/AQD. 2014. Report of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia, 5-7 March 2014, Iloilo City, Philippines. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines; 24 p

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Enabling the Freshwater Fish Culture Champions of Cambodia to Pull Through Difficult Times

Chin Leakhena

The freshwater aquaculture sub-sector has been playing a crucial role in the economic development of Cambodia as well as in enhancing the livelihoods of the country's rural people. Thus, the country has been exerting efforts to maintain the pace of its freshwater aquaculture development through a steady supply of locally-produced and quality fish seeds, and eliminate dependence of aquaculture on wild seeds through the development of sustainable fish seed production technologies. Nonetheless, the country's aquaculture development has encountered impediments that include inadequate supply of water especially in major aquaculture provinces and insufficient numbers of nursery ponds that limit production of fish seeds in large quantities. The limited number of quality broodstocks also contributes to the instability of fish seed supply while poor water quality management in grow-out ponds leads to low production yield, affecting the country's aquaculture development thrusts. Left alone, stakeholders of the country's freshwater aquaculture sub-sector are unable to address these concerns for lack of resources among other things. Therefore, it would be necessary for the Government to continue providing support to the country's fish seed producers and fish grow-out farmers, because with sufficient support, the roles in and contributions of these stakeholders to the sustainable development of freshwater aquaculture of the country could be enhanced. A glimpse of the lives of these important stakeholders through their socio-economic profiles are summarized in this article while recommendations are offered with the hope that the Government would take a closer look at these stakeholders and help them pull through difficult times so that they could enhance their contribution to the sustainable development of the country's freshwater aquaculture sub-sector.

The freshwater aquaculture sub-sector of Cambodia has been exhibiting great potentials to enhance its role in increasing the country's total fisheries production and eventually improve the economic condition of the country. As shown in **Table 1**, freshwater aquaculture contributed about 9.6% annually to the country's total fisheries production in terms of volume during the past five years, and if properly managed, such production trend could continue to rise in the coming years. In terms of value, freshwater aquaculture contributed about 40% annually to the total value of the country's fisheries production, which is considerably significant for the country's economic development. The increasing trend of the country's fish production from freshwater aquaculture could be attributed to the efforts of the Royal Government of Cambodia to intensify the production of locally-produced seeds by providing assistance to fish seed growers in terms of capacity building (Chin, 2014). The country also encourages fish grow-out farmers to patronize the seeds from local fish seed producers and for them to minimize dependence on imported fish seeds the costs of which are beyond their immediate reach, as well as on seeds from the wild to decrease pressure on the natural stocks.

Table 1. Fisheries production of Cambodia (2008-2012): Quantity (Qty) in thousand metric tons (MT); Value in million US$

	2008		2009		2010		2011		2012	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Capture Fisheries	**496.6**	**255.5**	**569.6**	**445.6**	**490.0**	**-**	**559.7**	**-**	**638.0**	**-**
Marine	66.0	-	75.0	110.7	85.0	-	114.7	-	110.0	-
Inland	430.6	255.5	494.6	334.9	405.0	-	445.0	-	528.0	-
Aquaculture	**39.8**	**61.8**	**50.0**	**88.0**	**60.0**	**-**	**72.0**	**126.9**	**90.0**	**-**
Mariculture	1.4	3.9	4.9	19.7	-	-	2.6	8.1	-	-
Brackishwater	-	0.4	0.1	0.8	-	-	-	-	-	-
Freshwater	38.4	57.5	45.0	67.5	60.0	-	69.4	118.8	90.0	-
Total	**536.4**	**317.3**	**619.6**	**533.6**	**550.0**	**-**	**631.7**	**126.9**	**728.0**	**-**

Sources: SEAFDEC (2014), SEAFDEC (2013), SEAFDEC (2012), SEAFDEC (2011), SEAFDEC (2010)

General Socio-economic Profile of Cambodia

Cambodia covers a total area of 181,035 km^2, and is surrounded by low mountains and lowlands where the Mekong River runs across from Lao PDR to Viet Nam. About 86% of the country is within the Mekong catchment area, and has extensive mangrove forests but with very short coastline of 440 km. Serving as a natural reservoir of the Mekong River system, the Tonle Sap Great Lake has an area of 2500-4000 km^2 in the dry season that could expand to 10,000-15,000 km^2 in wet season, flooding about 4800 km^2 of forest areas (Chin, 2013). Topographical and meteorological conditions make the water level of the Mekong River fluctuate by more or less 10 m between the dry and wet seasons, annually inundating and flooding most of the lowlands including rice fields during the wet season but becoming very arid in the dry season, making such areas also prone to natural calamities such as floods in the wet season and drought in the dry season.

The World Population Review (2014) indicated that the population of Cambodia is estimated to be more than 15 million in 2014 but the demographics of the country had been greatly affected by the civil war in mid 1970s, and as a result about 50% of its population is under 25 years old. In 2011, the country's population of about 14.7 million was women-dominated with a ratio of 100 female: 96 male (World Population Review, 2014). Cambodia remains one of the poorest countries in Southeast Asia with approximately 4 million people living on less than US$ 1.25 per day, most of whom had been inadequately educated and lacking in productive skills, particularly in the countryside where basic infrastructures are also limited (Index Mundi, 2014).

Socio-economic Profile of Fish Seed Producers and Grow-out Farmers: Case Study

Two provinces of Cambodia, *i.e.* Takeo and Kampong Speu Provinces, were chosen for the case study considering that most fish producers are located in these provinces, and largely support the country's small-scale fish hatcheries and grow-out industries (Chin, 2013). As shown in **Table 2**, Takeo Province accounted for about 36% of the country's 53,452 units of culture ponds, 13% of the country's 280 units of fish hatcheries, and 8% of the country's 738 community refuge ponds. Meanwhile, Kampong Speu accounted for about 4% of the country's total number of culture ponds, 9% of the country's total number of hatcheries, and 24% of the country's total number of refuge ponds.

In Takeo Province, freshwater fish species had been mostly produced in culture ponds and in Kampong Speu in community refuge ponds (**Table 2**). Managed by local communities, community refuge ponds are mainly used for fish spawning, where the resulting fish fingerlings and juveniles are released and allowed to migrate to inundated rice fields through connecting canals. In 2011, the freshwater fish species produced in culture facilities of Cambodia comprised mainly the pangas catfish (*Pangasius* spp.) at 26,400 MT; silver barb (*Barbonymus gonionotus*) 12,600 MT; snakeskin gourami (*Trichogaster pectoralis*) 7,300 MT; striped snakehead (*Channa striata*) 7,300 MT; and cyprinids 6,840 MT (SEAFDEC, 2013). Other species also contributed to the country's total production from freshwater aquaculture such as catfishes (*Clarias* spp.) at 1,950 MT, Nile tilapia (*Oreochromis niloticus*) 2,000 MT, Hoven's carp (*Leptobarbus hoeveni*) 1,800 MT, common carp (*Cyprinus carpio*) 1,650 MT, and other species that include climbing perch, silver carp, grass carp, and bighead carp.

General Profile of Kampong Speu Province

Much of Kampong Speu Province (**Fig. 1**) is rural, with a population of 0.69 million (0.327 million men and 0.361 million women) in 2004 (CIPS, 2004) and 0.717 million in 2008 (GPCC, 2008). The average household size is

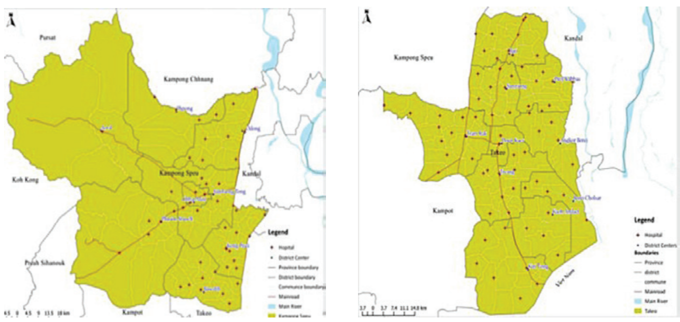

Fig. 1. Kampong Speu Province (*left*) and Takeo Province (*right*) in Cambodia

Table 2. Freshwater aquaculture facilities in Takeo and Kampong Speu Provinces, Cambodia (as of 2012)

Province	Culture Ponds	Culture Cages	Hatcheries			Community Refuge Ponds
			Total	Private	Public	
Takeo	19,146	12	37	36	1	58
Kampong Speu	1,824	-	24	23	1	173
Country Total	**53,452**	**3,883**	**280**	**266**	**14**	**738**

Source: Chin (2014) adapted from FIA (2012)

5.3, and approximately 25% of the total households are headed by female. Child population (0-14 years old) is approximately 40%, while elderly population (≥ 65 years old) is approximately 4%. The population density is 98 people per km^2, which is slightly higher than the national average of about 83 people per km^2.

General Profile of Takeo Province

Takeo Province (**Fig. 1**) has a population of 0.89 million (with 107 female to 100 male ratio) in 2004 (DIOS, 200) and 0.844 million in 2008 (GPCC, 2008). The average household has 5.0 members and approximately 41% of the total households are headed by female. Child population (0-14 years old) is approximately 40%, while elderly population (≥ 65 years old) is approximately 5%. The Province's population density of 250 people per km^2 is significantly higher than the national average.

Sites of the Case Study

Two districts were considered as specific sites for the study, namely: Basedth in Kampong Speu and Tram Kak in Takeo Province (**Fig. 2**). Basedth District, which is divided into 15 communes and 218 villages, has a total land area of 28,371 ha of which 5,320 ha is forest areas, 18,665 ha is cultivated land, and construction area of 4,386 ha (NCDD, 2009). Basedth District is bordered in the south by Tram Kak District of Takeo Province (Takeo Provincial Office, 2008). Meanwhile, Tram Kak District has an area of 54,694 ha of which 35,677 ha is devoted to agriculture, 6,618 ha for construction, and the remaining 10,239 hectares for other land uses (NCDD, 2009). It is divided into 15 communes and 244 villages and is bordered in the north by Basedth District of Kampong Speu Province (Takeo Provincial Office, 2008).

Fig. 2. Case study sites: Basedth in Kampong Speu Province, and Tram Kak in Takeo Province

From a list of aquaculture members available at the Basedth and Tram Kak Districts, the respondents comprising fish seed producers and grow-out farmers were chosen through systematic random sampling (Chin, 2013). As a result, 23 fish producer-respondents from the two districts were chosen, while 60 respondents were selected from the two districts' total number of fish grow-out farmers (**Table 3**).

Face-to-face interviews were conducted with the respondents, while interviews were also conducted with focus groups, such as officers from the Fisheries Administration Cantonment, Division and Sangkat Fisheries Offices, and Commune Chiefs and NGOs involved in aquaculture extension projects in the Districts. The primary data obtained from the respondents included information related to fish seed production and grow-out farming in Basedth and Tram Kak Districts (**Box 1**).

Moreover, observations were also made during the field survey to collect complementary information such as physical, social, economic and environmental conditions of the study sites and overall life style of the people. Key informants were interviewed to obtain significant information on regulations in aquaculture, plans and ways to address concerns related to local marketing of fish seeds to improve local livelihoods. Formal group discussions with fish seed producers and fish grow-out farmers were also

Table 3. Sample size used for the case study

Type of fish farmers	Study sites	Total number of fish farmers	Number of samples derived	% of sample to total fish farmers
Fish hatchery operators	Basedth	4	4	100.0%
	Tram Kak	19	19	100.0%
Fish grow-out farmers	Basedth	995	30	3.0%
	Tram Kak	4,981	30	0.6%

Source: Adapted from Chin (2013)

Box 1. Primary data gathered from study respondents

• General information • Sources of income • Activities in hatchery operations • Fish consumption and fish seed production • Fish seed customers	• Facilities and equipment • Breeding management • Hatchery management • Training/meetings/ seminar on quality improvements	• Perceptions on local fish seeds • Fish seed market (supply, demand, fish demand in a year) • Source of inputs and related supply

conducted while secondary information was collected from journals, fisheries sector development plans and strategy in Cambodia, books, reports, thesis, website, and libraries as well as local authorities, and NGOs.

Results and Discussion

The socio-economic profile of aquaculture farmers in Cambodia, championed by its fish seed producers and grow-out farmers, is summarized from the results of the questionnaire surveys as well as through actual observations, and discussions with concerned stakeholders.

General Profile of the Fish Seed Producers

Generally, the number of female involved in fish seed production is less than that of male. In Takeo Province, only two out of 19 fish seed producers are women. Meanwhile, there is only one female out of four fish seed producers in Kampong Speu Province (**Table 4**). The high proportion of men involved in fish hatchery activities in the study sites could be due to the heavy manual work in hatchery operations (FAIEX, 2009).

From actual observation however, men and women have equal roles in actual fish hatchery operations. While men are involved in fish breeding as well as in draining water and collecting the fish seeds for sale, women have been preparing the materials for breeding, *e.g.* hormones, chemicals, and taking care of fish larvae, *e.g.* feeding, checking water quality, health monitoring, and marketing of fish seeds. Nevertheless, the roles of women in fish hatchery activities are still not fully appreciated in spite of the many fora that discussed gender and development in fisheries at the global level (Needham, 2011). As part of the Government's effort to address the over-all needs of fishers and support the country's development programs that aim to improve fishers' livelihoods, the Royal Government of Cambodia encourages the women to be more actively involved in fish culture activities (Chin, 2013).

Table 4. Gender of fish seed producers (n=23)

Gender	Takeo Province		Kampong Speu	
	No.	%	No.	%
Female	2	26	1	25
Male	17	74	3	75
Total	**19**	**100**	**4**	**100**

Source: Adapted from Chin (2013)

Table 5. Age levels of fish seed producers (n=23)

Age group	Takeo Province		Kampong Speu	
	No.	%	No.	%
24-40 (young)	5	26.3	1	25.0
41-50 (median)	5	26.3	0	0.0
51-68 (elder)	9	47.4	3	75.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

The ages of the respondents ranging from 24 to 68 years old exhibited a significant difference in the two Provinces. Although the ages of fish seed producers in the young group (24-40 years old) and median group (41-50 years old) of Takeo Province are not significantly different, such trend is the opposite of Kampong Speu. For the two provinces, the numbers in the median group and elder group (51-68 years old) are significantly different as shown in **Table 5**. Age of the fish seed producers is a very important factor in fish hatchery management. While the median and elder age groups are generally well-organized in management, *e.g.* budget control, decision-making in day-to-day activities, in view of their experience and enhanced skills, those in the median group are generally more adept in hatchery management because of their enhanced capability and agility. Meanwhile, the young and elder age groups might not contribute much in hatchery operations because the young groups are more concerned about pursuing their studies while the elder age groups are putting more efforts in civic and spiritual activities.

In the three age groups, the educational levels are significantly different (**Table 6**). Educational background is another essential factor in hatchery management, to be able to understand and grasp hatchery technologies which keep on evolving new methods and practices, and adapt new technologies in their hatcheries. More particularly, hatchery operators should always keep abreast of the development in health management of seed stocks, to make their hatchery operations sustainable. Comparing with the study conducted by CSES (2007), results of the survey indicated higher number of fish seed producers in the study sites who attained

Table 6. Educational attainment of fish seed producers (n=23)

Age group	Vocational		Primary		Secondary		Higher level		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
24-40 (young)	0	0.0	2	8.7	2	8.7	2	8.7	**6**	**26.1**
41-50 (median)	0	0.0	1	4.3	3	13.1	1	4.3	**5**	**21.7**
51-68 (elder)	2	8.7	3	13.1	4	17.3	3	13.1	**12**	**52.2**
Total	**2**	**8.7**	**6**	**26.1**	**9**	**39.1**	**6**	**26.1**	**23**	**100.0**

Source: Adapted from Chin (2013)

higher educational levels (26%) than those in agricultural households (10%) who are not usually interested in getting higher education. The Fisheries Administration (FiA) of Cambodia regularly conducts extension-cum-training on fish hatchery operations for fish hatchery operators as well as fish seed buyers, to compensate for the inadequacy of information materials in the study sites, *e.g.* manuals of operation, guidelines, which could affect the decision-making capability of most hatchery operators.

Average family size of fish seed producers in Takeo Province at 3.4 members is significantly different from that of Kampong Speu at 4.5 members (**Table 7**) but the average family size of the fish seed producers in these two provinces is slightly lower than the country's average of 5 members. Family size could have certain impacts in hatchery management, for although small size families could earn more due to lesser family expenditures but they have to source labor force from outside the family. Meanwhile, big family size could take advantage of free labor from within the family thus saving on labor costs, but could be spending more on family expenses. The maximum area owned by fish seed producers is 2.0 ha/family (**Table 8**), and the average sizes of land holdings in Takeo at 0.94 ha/family and in Kampong Speu at 0.91 ha/family are not significantly different.

Land is an important asset of fish seed producers, as those with large land holdings could expand their hatcheries to supply the increasing demand for fish seeds but those with small land holdings produce limited volumes of seeds because of limited number of nursing ponds, broodstock ponds, and no place to construct large water reservoirs for hatchery operations. In both provinces, hatcheries are constructed close to the operators' houses making it easy for them to take care of the seed stocks. The average land holdings of fish seed producers at about 0.90 ha/family is smaller than the national level of agricultural land holdings which in 2009 was 1.4 ha/family (NCDD, 2010).

Table 7. Family size of fish seed producers (n=23)

Family size (people)	Takeo Province		Kampong Speu	
	No.	%	No.	%
2-3 member group	11	57.9	3	75.0
>3-5 member group	7	36.8	0	0.0
>5-10 member group	1	5.3	1	25.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Table 8. Land holdings of fish seed producers (n=23)

Size of land holdings	Takeo Province		Kampong Speu	
	No.	%	No.	%
0.3-0.5 ha (small)	5	26.3	1	25.0
0.6-1.0 ha (medium)	9	47.4	2	50.0
1.1-2.0 ha (large)	5	26.3	1	25.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Table 9. Minor occupations of fish seed producers (n=23)

Minor occupations	Takeo Province		Kampong Speu	
	No.	%	No.	%
Rice farming	11	57.8	4	100.0
Small business	2	10.5	0	0.0
Government official	4	21.1	0	0.0
Veterinary/livestock	1	5.3	0	0.0
Mechanic/technician	1	5.3	0	0.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Table 10. Annual incomes of fish seed producers from hatchery operations (n=23)

Income categories Million riels (KHR)	Takeo Province		Kampong Speu	
	No.	%	No.	%
1.000-10.000 (low)	12	63.2	3	75.0
10.001-20.000 (medium)	2	10.5	0	0.0
20.001-80.000 (high)	5	26.3	1	25.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Although fish seed production is a main occupation, some families are also involved in other activities for additional family incomes (**Table 9**). For example, rice farming is only a minor occupation of fish seed operators (about 58%) from Takeo Province but fish seed producers in Kampong Speu are engaged in rice farming, the backbone of Cambodia's agricultural sector. FAO/WFP (2012) has reported that about 80% of the population in Tram Kak and Basedth Districts are rice farmers contributing about 25% to the country's agricultural GDP in 2006.

About 63% of the seed producers from Takeo and 75% from Kampong Speu receive low incomes from hatchery operations (**Table 10**). However, some fish seed producers get additional income from agriculture as well as remittances from relatives and family members working outside the provinces (**Fig. 3**).

For fuel requirements of the fish hatcheries, fish seed producers depend more on battery followed by public electricity supply, solar, and biogas (**Fig. 4**). The cost of using battery is cheaper at 200,000 KHR/year than that of public electricity system at 300,000 KHR/year, while using solar and biogas fuel is the most expensive at 1.3 million KHR/year and 1.0 million KHR/year, respectively. Starting in 2012, their utilization of public electric supply for fish hatchery operations had increased when the public electricity system had improved. Generally, fish seed producers could

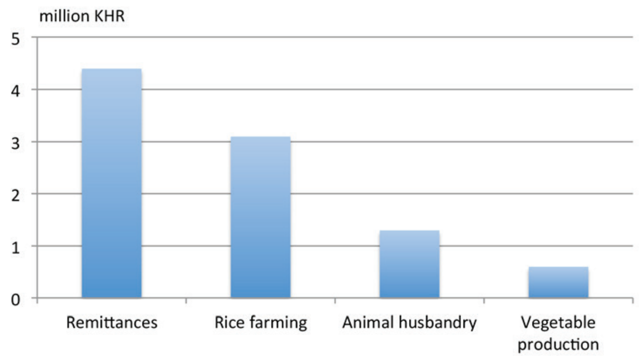

Fig. 3. Sources of other annual incomes of fish seed producers from Takeo and Kampong Speu in million KHR

Source: Adapted from Chin (2013)

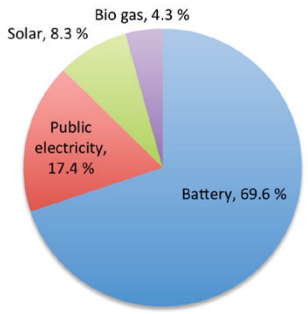

Fig. 4. Sources of fuel for fish hatchery operations in Takeo and Kampong Speu (n=23)

Source: Adapted from Chin (2013)

Table 11. Source of drinking water of fish seed producers

Water Sources	Takeo Province		Kampong Speu	
	No.	%	No.	%
Dug Well	1	4.2	17	70.8
Rainfall	22	95.8	6	29.2
Total	**23**	**100.0**	**23**	**100.0**

Source: Adapted from Chin (2013)

Table 12. Fish consumption of fish seed producers

Fish consumed (kg/family/year)	Takeo Province		Kampong Speu	
	No.	%	No.	%
83-100	3	15.8	1	25.0
101-300	12	63.2	1	25.0
301-600	4	21.0	2	50.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

not avail of public water supply for drinking and other household needs since water supply is inadequate. Thus, during the rainy (wet) season, fish seed producers use rain water for drinking and other needs, while in the dry season, their main source of drinking water is dug wells (**Table 11**). Several respondents own dug wells, *i.e.* 8 in Takeo and 2 in Kampong Speu, serving also as common property resource among neighboring households. However, insufficient water supply remains a major problem in these provinces, especially during the dry season, *i.e.* April to May, before the rainy season sets in when most of dug wells could dry up. For hatchery operations, fish seed producers also make use of water from community ponds, reservoirs or lakes that had been filled up with rain water.

Seed Producers' Fish Consumption

Rice and fish form the basic part of Cambodian household diet (FiA, 2010). However, fish seed producers from Takeo consume on an average, 153 kg of fish/family/year and 285 kg of fish/family/year for Kampong Speu (**Table 12**) or an average of about 54.8 kg/capita/year compared with the country's average fish consumption of at least 52.4 kg/capita/year (Chin, 2013).

Fish and other aquatic resources make up over 80% of the protein intake of Cambodians which could increase to 90% in fish-dependent provinces (Hortle, 2007), but the estimated average daily consumption of fish could vary depending on the season when the supply and demand of fish change, especially during the rice planting season (Sophearith, 2005). Fish preserved in the form of "prahok" when fish supply is abundant, is consumed by hill tribes during the rice planting season although cultured fish also plays a major role of supplying the protein requirements when wild captured fish is not available, especially during the dry season. Under such circumstances, aquaculture has been promoted at the community level to reduce dependence on fish captured from the wild (Nam, 2005). Therefore, aquaculture activities had been promoted in Cambodia with the objective of producing more fish for the daily consumption of its populace.

Table 13. Experience of fish seed producers *vs*. income gained from seed production (n=23)

Years of experience in fish seed Production	Annual income (in million KHR): 1 USD = 4000 KHR							
	1.000-10.000		10.001-20.000		20.001-80.000		Total	
	No.	%	No.	%	No.	%	No.	%
2-5 years	12	80.0	0	0.0	0	0.0	12	52.2
6-9 years	2	13.3	2	100.0	3	50.0	7	30.4
10-13 years	1	6.7	0	0.0	3	50.0	4	17.4
Total	**15**	**100.0**	**2**	**100.0**	**6**	**100.0**	**23**	**100.0**

Source: Adapted from Chin (2013)

Seed Producers' Practices

The respondents had been producing fish seeds at small-scale levels since 1999, and 23 hatcheries had been established from 1999 until 2011, *i.e.* 19 in Takeo and 4 in Kampong Speu with support from various organizations and the Fisheries Administration of Cambodia. Most fish seed producers own breeding and hatchery tanks, water storage tanks, and broodstock and nursery ponds. In addition, they also own water pumps, generators, dug wells, and other equipment but most of them are not well-experienced in hatchery operations. About 52% had only 2-5 years experience while about 30% had experience that spans from 6 to 9 years (**Table 13**). For being less-experienced, fish seed producers could earn low incomes that range from 1.000 to 10.000 million KHR (1 USD = 4000 KHR). Oftentimes, less-experienced seed producers gain less customers and low consumers' trust as the quality of their fish seeds could be low with high mortality due to handling. In order to earn considerable income from seed production, fish seed producers should have at least 5 years of experience in the hatchery industry.

Table 14 shows that the amount of fertilizer used and total seeds produced are statistically different. Most fish seed producers who used low amount of fertilizer got low production but using large quantity of fertilizer could also lead to low production. Furthermore, there was also a statistical difference between the amount of fuel used and total seeds produced as shown in **Table 15**.

Most fish seed producers from the two provinces have been confronted with poor water quality in their hatcheries, *i.e.* 90% from Takeo, 75% from Kampong Speu (**Table 16**).

Table16. Fish seed producers encountering poor water quality

Water quality Problem	Takeo Province		Kampong Speu	
	No.	%	No.	%
Yes	17	89.5	3	75.0
No	2	10.5	1	25.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Table 17. GnRH and Motilium used by seed producers

Species	No farmers	%	GnRH (µg/kg)	Domperidone (mg/kg)
Common carp	23	20.4	5-10	25.0
Silver carp	23	25.4	5-10	25.0
Silver barb	23	15.4	5-10	50.0
Total	**19**	**100.0**	**4**	**100.0**

Source: Adapted from Chin (2013)

Some addressed the problem by filtering the water (using sand and gravel) before pumping it to hatchery tanks and nursery ponds.

Fish seed producers get their broodstocks from various sources, such as from fish farmers' network ponds, seed producers' self-operated ponds, and government-operated broodstock ponds. Broodstocks of common carp, silver carp and silver barb are mostly kept in mixed-species broodstock ponds to conserve water especially during dry season, and separated by sex only during the wet season. By nature, most carp species spawn during the rainy season from June to August every year, but in the hatcheries, carps could spawn twice a year, *i.e.* February to April, and May to October.

Table 14. Amount of fertilizer used *vs*. fingerlings produced in 2012 (n=20)

Amount of Fertilizer used (kg)	Total production (million fingerlings)							
	0.000-0.150		0.151-0.350		0.351-0.715		Total	
	No.	%	No.	%	No.	%	No.	%
5-30	14	87.4	0	0.0	1	50.0	15	75.0
31-60	1	6.3	0	0.0	0	0.0	1	5.0
61-100	1	6.3	2	100.0	1	50.0	4	20.0
Total	**16**	**100.0**	**2**	**100.0**	**2**	**100.0**	**20**	**100.0**

Source: Adapted from Chin (2013)

Table 15. Amount of gasoline used *vs*. fingerlings produced in 2012 (n=23)

Amount of gasoline used (liters)	Total production (million fingerlings)							
	0.000-0.150		0.151-0.350		0.351-0.715		Total	
	No.	%	No.	%	No.	%	No.	%
10-100	17	100.0	1	50.0	0	0.0	18	78.3
101-200	0	0.0	0	0.0	2	50.0	2	8.7
201-450	0	0.0	1	50.0	2	50.0	3	13.0
Total	**17**	**100.0**	**2**	**100.0**	**4**	**100.0**	**23**	**100.0**

Source: Adapted from Chin (2013)

Table 18. Types of food given to fish seeds at various stages of development

Species	Length of fish seeds			
Silver barb	3-10 mm	>10-15 mm	>15-75 mm	>75 mm
	rotifer (70-200 mm)	rotifer, cladecerans, copepods, zooplanktons	Rotifer, cladecerans, copepods, zooplanktons, phytoplanktons	organic food, all types of phytoplanktons
Common carp	6-10 mm	10 mm		
	rotifer (70-200 mm)	all types of phytoplanktons		

Source: Adapted from Chin (2013)

However, silver carp spawns only when the temperature is lower, *i.e.* May to August every year. Fish seed producers use different dosages of gonadotropin-releasing hormone (GnRH) and Motilium (Domperidone) to induce spawning of various species of carps (**Table 17**).

Although the commercial size of fish fingerlings for stocking is 5.00-7.00 cm, the average size of seeds produced in these provinces for all species is only 4.56 cm, *i.e.* the average size of common carp is 4.30 cm, silver carp is 5.30 cm, and silver barb is 4.10 cm. Survival rates in nursery ponds is low because of predation by aquatic insects and poor water quality. In nursery ponds, the different species are given various foods depending on the stages of development as shown in **Table 18**.

Constraints in Fish Seed Production

The main constraint in small-scale freshwater aquaculture in Cambodia is related to technical and environmental aspects. Most of fish seed producers are being confronted with broodstock management problems due to high density and mixed-species stocking, poor water quality in the dry season, inadequate water supply, high temperature, limited nursing areas, drought, and predation, *e.g.* high quantity of zooplanktons in nursing ponds. Furthermore, fish seed producers should always have sufficient supply of hormones, adequate extension support, complete hatchery facilities, and adequate marketing skills. Broodstock management, a critical aspect in seed production, seems to impede hatchery operations in Cambodia due to decline in broodstock quality (Olivier, 2002). However, fish seed producers have gained better techniques through training, extension, exchange of experiences, and demonstrations within the fish seed producers' network, enhancing their know-how and skills. As a result, partial replacement of broodstocks is conducted while locally-produced fingerlings are well-grown in hatcheries. Imported fingerlings have been found not suitable for culture in ponds as these could not adapt to the different situation in Cambodia such as water, temperature, and more particularly food since in rural areas of Cambodia, fingerlings are fed natural or organic food instead of artificial diets (Producers' Group Discussion, 2012). However, fish seed producers seem to use the same broodstock as source for their hatchery operations. The number of fish seeds produced depends on the demand for fish seeds and capacity of the hatcheries, but about 217,300 fingerlings are produced per hatchery run, comprising fingerlings of silver barb, silver carp, common carp, and other species, *i.e.* mrigal, rohu, walking catfish and pangasius catfish. However, the volume of seeds produced had decreased by 13% from 2010 to 2011, and by 7% from 2011 to 2012 due to improper broodstock management, and for using the same broodstock over and over again. Cross-breeding and in-breeding led to deteriorating quality of the seeds while the quality of water also adds to the problem since water in broodstock ponds is drained only once a year.

Fish Seed Market

The sources of local fish seeds in Takeo Province are grow-out farms (85%), middlemen (5%), nursery farms (3%), government farms (2%), NGOs (2%), and other markets, *e.g.* home-operated markets and other small projects (4%). In Kampong Speu Province there are only two sources, these are the grow-out farms (86%) and middlemen (14%). Buyers for fish seeds come from far-flung provinces as well as nearby areas (**Fig. 5**). Transportation expenses account for the highest cost of operations in freshwater fish culture in Cambodia considering the distance of fish seed producers from buyers' farms, *e.g.* farms located in Preah Sihanouk, Kampot, Poipet, Battambang, Preah Vihear, Kampong Thom, Kampong Cham, Rattana Kiri, and Mondol Kiri.

General Profile of the Fish Grow-out Farmers

Freshwater aquaculture in Cambodia started to develop in 2000 with two (2) fish grow-out farmers. After the country's

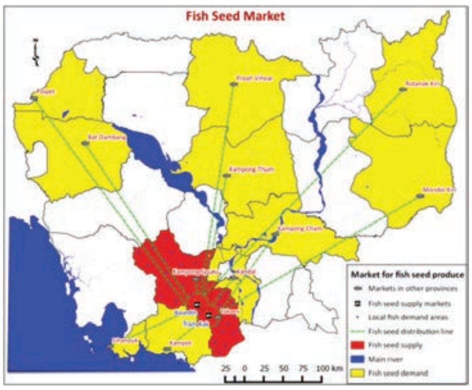

Fig. 5. Market of fish seeds produced in Takeo and Kampong Speu Provinces

Source: Adapted from Chin (2013)

Table 19. Gender of fish grow-out farmers (n=60)

Gender	Takeo Province		Kampong Speu	
	No.	%	No.	%
Female	5	16.7	3	10.0
Male	25	83.0	27	90.0
Total	**30**	**100.0**	**30**	**100.0**

Source: Adapted from Chin (2013)

Table 20. Age levels of fish grow-out farmers (n=60)

Age group	Takeo Province		Kampong Speu	
	No.	%	No.	%
26-45 years old (young)	14	46.7	12	40.0
46-60 years old (median)	15	50.0	11	36.7
61-72 years old (elder)	1	3.3	7	23.3
Total	**30**	**100.0**	**30**	**100.0**

Source: Adapted from Chin (2013)

Freshwater Aquaculture Improvement and Extension (FAIEX) Project provided financial and technical assistance to farmers in Kampong Speu and Takeo Provinces, small-scale aquaculture has improved and the number has increased to 60 grow-out farmers as of 2012. The FAIEX Project encouraged local communities to culture fish in order to promote cheaper price of fish in rural areas in good quality and quantity. Men and women contribute significantly to freshwater fish culture operations although more men are involved than women, *i.e.* 83% for Takeo and 90% for Kampong Speu (**Table 19**), which is not different from that of the ratio in fish seed production.

The ages of fish grow-out farmers vary from 26 to 72 years old. Compared with the fish seed producers, the country's fish grow-out farmers appear older (**Table 20**). This suggests that many young Cambodians do not seem to be interested in aquaculture activities, and if they do, they start at later age, *e.g.* 24 years old for fish seed production and 26 years old for fish grow-out farming, or they could be more interested in pursuing their studies than go into fish culture activities. Some seek for jobs in nearby provinces or other countries while they are still very able to do laborious jobs. Nevertheless, Cambodians could also work until the later years of their lives, *e.g.* 68 years old for fish seed production and 72 years old for fish grow-out farming. Although only about 3% from Takeo Province belong to the elder age group, the number is higher at about 23% in Kampong Speu. Many elder people do not go to other places to find job and devote most of their time in small-scale fish culture in their districts. Moreover, fish farmers of the young age group (26-45 years old) and median group (46-60 years old) have higher educational attainment than those in the elder group (61-72 years old) as shown in (**Table 21**), where the young age group are highly educated (22%) with only about 13% of the elder group attended vocational training and/or primary school. Although about 37% of the fish grow-out farmers attended secondary school or higher level, this is higher than the national average of about 11% (MoP/NIS, 2010) suggesting that fish grow-out farmers could afford to pursue higher education. This figure is however lower than that of the fish seed producers which is about 65%.

Rice farming is also another occupation for most fish grow-out farmers, although one farmer from Takeo reported that he is a teacher (**Table 22**). However, some fish grow-out farmers are able to get additional income from other sources (*i.e.* off-farm and on-farm activities) as well as from remittances of members of their households who are working outside their districts as shown in **Fig. 6**. They could also derive additional income from selling/peddling other goods, rice farming, vegetable production, and animal husbandry. The average annual income per family in both provinces is 13,460,000 KHR, which is higher than the annual income-poverty line in rural areas reported by World Bank (2009) and JICA (2010) at 863,955 KHR per capita or about US$ 864/family, respectively.

Table 22. Other occupations of fish grow-out farmers (n=60)

Other Occupations	Takeo Province		Kampong Speu	
	No.	%	No.	%
Agriculture (*e.g.* rice farming, animal husbandry, vegetable production)	29	96.7	30	100.0
Teacher	1	3.3	0	0.0
Total	**30**	**100.0**	**30**	**100.0**

Source: Adapted from Chin (2013)

Table 21. Educational attainment of fish grow-out farmers (n=60)

Age group	Level of education									
	Vocational		Primary		Secondary		Higher level		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
26-45 (young)	3	50.0	7	21.9	13	72.2	3	75.0	26	43.3
46-60 (median)	2	33.3	18	56.2	5	27.8	1	25.0	26	43.3
61-72 (elder)	1	16.7	7	21.9	0	0.0	0	0.0	8	13.4
Total	**6**	**100.0**	**32**	**100.0**	**18**	**100.0**	**4**	**100.0**	**60**	**100.0**

Source: Adapted from Chin (2013)

Table 23. Source of fuel used by fish grow-out farmer-respondents (n=60)

Power Source	Takeo Province		Kampong Speu	
	No.	%	No.	%
Government electricity supply	2	6.7	0	0.0
Generator	1	3.3	0	0.0
Kerosene	1	3.3	1	3.3
Battery	26	86.7	29	96.7
Total	**30**	**100.0**	**30**	**100.0**

Source: Adapted from Chin (2013)

Table 24. Consumption of fish by fish farmers from Takeo and Kampong Speu (n=60)

Fish consumed (kg/family/year)	Takeo Province		Kampong Speu	
	No.	%	No.	%
100-140	10	33.3	20	66.7
141-240	16	53.3	10	33.3
241-360	4	13.4	0	0.0
Total	**30**	**100.0**	**30**	**100.0**

Source: Adapted from Chin (2013)

Table 25. Size of pond areas in Takeo and Kampong Speu (n=60)

Pond size (m^2)	Takeo Province		Kampong Speu	
	No.	%	No.	%
95-300	23	76.7	14	46.7
301-700	7	23.3	12	40.0
701-1,100	0	0.0	4	13.3
Total	**30**	**100.0**	**30**	**100.0**
	ave = 258 m^2		ave = 417 m^2	

Source: Adapted from Chin (2013)

Table 26. Number of fish seeds (heads) stocked per household in Takeo and Kampong Speu (n=60)

Fish seeds per family (heads)	Takeo Province		Kampong Speu	
	No.	%	No.	%
285-1,000	26	86.7	17	56.7
1,001-2,100	4	13.3	9	30.0
2,101-3,300	0	0.0	4	13.3
Total	**30**	**100.0**	**30**	**100.0**
	ave = 774 heads		ave = 1252 heads	

Source: Adapted from Chin (2013)

Fish grow-out farmers also reported that battery is their main source of fuel followed by government electricity supply for Takeo Province and kerosene for Kampong Speu Province (**Table 23**). Using kerosene gives them the lowest expenditure on fuel at KHR 171,000/family/year (1 USD = KHR 4,000), while using generator gives the highest expenditure at KHR 460,800.00. Using battery and government electricity supply system could entail

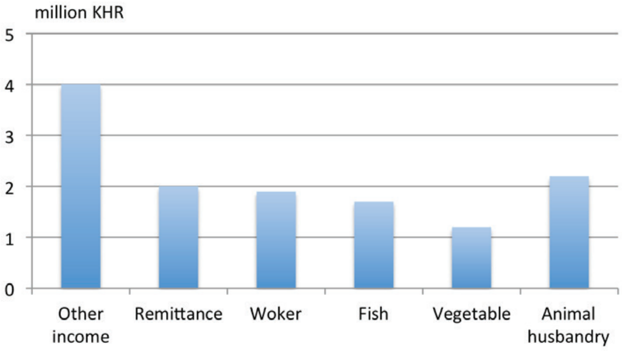

Fig. 6. Annual income of fish grow-out farmers (in million KHR)
1 USD = 4,000 KHR

expenditures of KHR 382,470 and KHR 315,840/family/year, respectively.

Grow-out Farmers' Fish Consumption

Fish grow-out farmers from Takeo consume higher amount of fish (166 kg/family/year) than those from Kampong Speu Province (129 kg/family/year), exhibiting a significant difference in the average of annual fish consumption between Takeo and Kampong Speu Provinces (average fish consumption is 148 kg/family/year) as shown in **Table 24**. Fish captured from the wild is mostly consumed in the wet season but during the dry season, they buy fish from various sources for family consumption (So Nam, 2005).

Grow-out Farmers' Practices

Fish grow-out farmers from Takeo and Kampong Speu Provinces practice proper pond preparation although only about 41% of the grow-out farmers remove mud after draining the pond. Grow-out farmers apply agriculture lime at 6.5 kg/100 m^2 and organic fertilizers during pond preparation to produce natural food and improve water quality, *i.e.* alkalinity that promotes growth of phytoplankton and zooplankton as food for the stocked fingerlings. The available on-farm organic fertilizers include farm-yard manure of cow, buffalo, pig, chicken, and duck, and green manure. Some grow-out farmers also apply off-farm commercial inorganic fertilizers (30 kg/100 m^2) including di-ammonium phosphate (DAP) and urea, but the average usage is 30 kg for organic fertilizers, 300 g of urea, and 100 g for DAP per 100 m^2, and in order to reduce the acidity of pond water, aquaculture lime is applied in the ponds. Most ponds in Takeo Province are small (77%) as well as those in Kampong Speu (47%) ranging from 95 to 1,100 m^2 (**Table 25**). The average pond area and depth is 338 m^2 with 2 m, respectively, but ideal for family-scale fish culture that could provide a family their main source for food and income.

Average stocking density of fish seeds is significantly different in the two provinces, where the average is 1,012 fingerlings/farmer/year (3 heads/m^2) as shown in **Table 26**. Grow-out farmers in Takeo and Kampong Speu obtain

Table 27. Size and corresponding price of fish seeds stocked in ponds in Takeo and Kampong Speu (n=60)

Species	Size range (cm)	Ave size (cm)	No. of farmers	% of total number of farmers	Price range (KHR/head)	Ave price (KHR/head)
Common carp	3.00-8.00	4.30	53	88.3	50-100	80
Silver carp	4.00-7.00	5.30	49	81.7	50-100	80
Silver barb	3.00-6.00	4.10	54	90.0	50-100	80
Other species	4.00-7.00	5.40	45	75.0	50-100	80

Source: Adapted from Chin (2013)

Table 28. Fish production per household in Takeo and Kampong Speu (n=58)

Production (kg/family)	Takeo Province		Kampong Speu	
	No.	%	No.	%
36-120	27	90.0	14	50.0
121-200	3	10.0	5	17.9
201-400	0	0.0	9	32.1
Total	**30**	**100.0**	**28**	**100.0**
	ave = 90 kg/family		ave = 163 kg/family	

Source: Adapted from Chin (2013)

fish seeds either through fish seed suppliers who come to farmers' houses to sell fish seeds or by going to fish seed suppliers. The latter allows the fish grow-out farmers to learn lessons on fish culture from the suppliers. However, majority of grow-out farmers go to local fish seed suppliers or producers to buy fish seeds in the wet season (88%) while only 12% buy fish seeds from local fish seed producers who come to their houses to sell fish seeds, in which case, healthy fingerlings are procured from reliable hatchery operators or suppliers. Ponds in the study areas are usually stocked with fingerlings of mixed species, *i.e.* silver barb, silver carp, common carp, and other species at the same time. The fingerlings which are smaller than 5.00-7.00 cm or 3.0-5.0 g fingerlings recommended by FiA, are properly stocked ponds that could retain water for only 5-6 months (JICA, 2010).

Six fish species are commonly cultured, these are four exotic fish species, namely: common carp, silver carp, tilapia, and mrigal, and two native species, *i.e.* silver barb and sutchi catfish (**Table 27**). The most popular fish stocked is silver barb with common carp while the three most frequently stocked fish species are the silver carp and other species (tilapia, mrigal, and sutchi catfish). The average size of the silver barb and common carp is at 4.00 cm, while the average size of silver carp and other species is 5.30 cm and 5.40 cm, respectively. Majority of the grow-out farmers adopt the polyculture system of fish farming as recommended by the FiA, *i.e.* stocking a mixture of different trophic level of fish species. However, the proportion of silver barb in small-scale culture facility is higher than silver carp and other species (tilapia, mrigal, and sutchi catfish) at 40%, 22%, 20%, respectively. Only few grow-out farmers stock their ponds with common carp and other species in a polyculture system.

In order to attain good production, fish are given supplementary feeds, *e.g.* kitchen wastes, duck weeds, termites, and vegetable wastes (*e.g.* leaves of cassava, potato, cabbage, morning glory). Rice bran is given at 2-3% of fish biomass to increase fish growth and production, but if kitchen wastes or duck weeds are given, the amount of rice bran given is reduced (FiA, 2006). Feed is given once or twice a day, the quantity of which increases with the size of fish. Green pond water indicates good plankton production, but fertilization could be increased when there is lack of plankton growth in the water (JICA, 2009). While July is the peak month for stocking and April is the peak for harvesting, some grow-out farmers stock their ponds with fingerlings in early June or late September so that early harvest could be done in February, and in May and June.

Quality and availability of water are important factors for fish culture as rainwater could only be collected from May to November. Thus, fish culture could only be conducted for an average duration of eight (8) months. Harvest starts as soon as fish reach table size or when water level of the pond goes below 50 cm, with the peak in the dry season. The average fish yield is statistically different with grow-out farmers from Kampong Speu Province getting the highest yield, while the lowest yield is experienced in Takeo Province (**Table 28**). All fish farmers stock their ponds only once per year and grow the fish at an average period of 8 months. Fish are regularly harvested many times during the culture period for family consumption, but final fish harvest is carried out in dry months, *i.e.* March and April, when pond water is lower than 0.5 m. Average fish production is 125 kg/family and the average fish yield is 37 kg/100 m^2, sizes of which vary depending on the species.

The difference in yield between the provinces Takeo and Kampong Speu is due to different pond sizes (ponds in Kampong Speu are bigger than those in Takeo), but the average yield per square meter is similar. In the rural areas of Cambodia, the most favorite fish species are carps and grow-out farmers could sell their fish in their house at a good price of 10,000 KHR/kg.

Factors that Influence Freshwater Fish Production of Cambodia

The factors that affect local small-scale fish farmers of Cambodia could be technical, economic, environmental, and institutional. Technical aspects refer to the methods in breeding, hatching, larval rearing and nursing, and pond culture taking into consideration the major facilities and equipments as well as the number of years of experience of hatchery operators and fish grow-out farmers. These factors have significantly influenced the technical capability of local small-scale fish farmers in Takeo and Kampong Speu Provinces. However, local fish farmers have expanded their facilities (JICA, 2009) and enhanced their technical capability expecting to increase the volume of fish seeds produced as well as the pond yields. Nevertheless, fish farmers could increase their production if only land area is available for additional nursing and grow-out ponds (Group Discussion, 2012).

Economic factors include operating costs for breeding, hatching and nursing the fish larvae, and fish culture, and more importantly the costs for water storage, hormones, equipment, and fuel. Due to the geographical situation of the sites, expenses for water storage which are higher than other operating costs, play a significant role in fish farm operations. Inadequate water supply could slow down fish production limiting the potentials for expanding fish farm operations, considering that local fish farmers use their own budget because loans are not only difficult to obtain but also large collateral is required in accessing loans. However, some fish farmers who are able to get financial support or subsidies from NGOs, have expanded the capacity of their small-scale hatcheries and fish farms (Viseth, pers.comm, 2012).

Although the environment of Takeo and Kampong Speu might be appropriate for fish culture, many fish farmers are still challenged with various constraints, such as long drought that results in insufficient amount of water available for breeding and nursing the fish larvae as well as culturing the fish to marketable size. Infrastructures that could bring the source of water, such as rivers, streams, and canals, closer to fish hatcheries and pond areas have always been inadequate. Being far from natural water bodies, fish farmers depend on rainwater and groundwater or dug-wells. Even if inadequate supply of water might not affect the fish seed producers, it could delay stocking of fish in grow-out ponds, and thus, considerable volumes of fish seeds could not be sold immediately. Specifically, the fish farmers have indicated that their production in succeeding years could be increased if sufficient supply of water is available (Producers Group Discussion, 2012).

Institutional support comes in the form of services and other facilities made available for improving the total fish production, and include existing rules and regulations, network of fish seed producers, NGOs funding fish seed production and pond development projects, and support from the Fisheries Administration of Cambodia. The fish farmers are aware of the regulations and laws on the country's aquaculture development as well as the efforts of the Government in promoting the expansion of their aquaculture ventures in accordance with the Fisheries Law. The Fisheries Administration (FiA) of Cambodia also encourages private hatcheries to make their broodstocks available for the local small-scale hatchery operators, and promotes the standard age and weight of broodstocks to be used for fish breeding to ensure that quality seeds are produced without diseases (FiA, 2010).

The Fish Seed Producers' Network was established in each province with capacity building provided by JICA and FiA. The Network supports the country's aquaculture development by identifying the needs of fish seed producers; addressing problems in hatchery activities especially on the technical, financial and marketing aspects; and ensuring a more adequate fish seed supply for fish farms in rural areas in terms of quality and quantity. Relevant aquaculture development projects in Cambodia have also received support from various donors not only technically but also financially to enhance aquaculture production.

The FiA maps the policy and vision for the country's national aquaculture development considering that aquaculture offers enormous long-term potential for the country's socio-economic development. However, the country's production from freshwater aquaculture mostly from small-scale fish culture operation had been fairly low. In order to achieve immediate growth in this sub-sector while also maintaining a pro-poor focus, the FiA intends to make major interventions by providing support to small and family-scale aquaculture development primarily through training, providing fish fingerlings, and establishing risk management systems. FiA also plans to promote its target of increasing fish seed production to 250,000,000 per year by the end of 2019; develop and implement a surveillance, monitoring and control system for fish disease outbreaks by the end of 2014; and conduct R&D for commercially viable production of indigenous species in cooperation with regional organizations, *e.g.* the Mekong River Commission (MRC). The FiA would develop comprehensive regulations and technical standards under the country's Fisheries Law to support the capability of the aquaculture sector to attain the set targets (FiA, 2010). Since access to markets is an important factor to sustain aquaculture activities, FiA makes necessary information available to stakeholders, specifically the market chain for hatchery, supply chain for inputs, and local distribution platforms. Connections between seed producers, nursery farmers, and fish grow-out farmers would be strengthened and newcomer-local network within the aquaculture domain would be established (FAO, 2007).

Conclusion and Recommendations

The socio-economic indicators of the fish seed producers and fish grow-out farmers in Takeo and Kampong Speu Provinces, particularly in terms of education, production and incomes appear good considering the setting of these two provinces which could be considered rural. However, fish seed producers seem to get higher income and attain higher educational levels than the fish grow-out farmers. Moreover, fish seed producers consume higher amount of fish than fish grow-out farmers. Nevertheless, fish farmers have sufficient resources to undertake aquaculture ventures as better source of alternative income. Fish seed production has already been an established enterprise in the two provinces despite incessant drought and limited water supply infrastructures. As could be deduced from the survey, most fish seed producers were successful during the rainy seasonal breeding season, *i.e.* end of February to the mid October, when rain water is sufficient. Generally, seeds produced locally are of good quality in terms of uniform size and age, bright color, fast growth rate, disease resistance, healthy, high survival rate, no environmental effect, and able to consume local food, in spite of few barriers such as lack of water and inadequate broodstock management. The distribution of fish seeds from the two provinces is widespread reaching the northwest provinces of the country close to Thailand to the northeast provinces located at the border with Viet Nam.

Meanwhile, fish grow-out farmers have obtained good experience in aquaculture after attending fish culture training courses provided by FiA. Their pond areas are suitable and adopt good practices such as pond preparation, fertilization, stocking density, feeding, pond management, that result in fair yield. Locally-produced fish seeds are made available through the provincial fish seed production network. The availability of imported fish seeds has collapsed and does not compete anymore with the locally-produced fish seeds as it did before, making fish seed enterprise a profitable business in the two provinces. Moreover, rural fish grow-out farmers have expressed their satisfaction with the support from the Government and NGOs and expressed the desire to expand their operations in the future.

Nonetheless, increasing the volume of fish seeds produced would involve two-pronged approaches, *i.e.* increasing the surface area of hatcheries as well as the quantity of fish seeds produced from each hatchery. Considering the limited land area available, it might not be possible for fish farmers to expand the size and capacity of their hatcheries and ponds. When the prohibitively expensive costs of fish production exceed the value of the produce, then aquaculture ventures would not be profitable and fish farmers would remain very poor. Therefore, in order to improve production efficiency and produce better yields, fish farmers should be able to use considerable amount of water necessary for hatchery operations as well as pond culture, with improved water quality and management, increase nursing areas and improve the quality of broodstocks that would produce good quality and disease-free seeds for stocking in culture ponds. Furthermore, in order to expand the market of locally-produced fish seeds, producers should encourage their customers to enhance the use of locally-produced seeds. In summary, to increase the total fish seed

Box 2. Short-term Recommendations

Local hatcheries are the most important sources of seeds for aquaculture in Cambodia. The FiA should therefore strengthen its partnership with NGOs to obtain financial support that would enable the conduct of activities that address the following concerns and eventually enhance the capacity of local hatcheries:

- Hatchery operations are small-scale and nursing areas are very limited. The Government and NGOs should encourage fish seed producers to specialize on the production of one species only to increase the survival rate and the overall quality of seeds;
- Few fish seed producers use settling tanks as source of water flowed into tanks or ponds. Therefore, improving the quality of water in settling tanks should be promoted, particularly during dry season when water is limited, *e.g.* use of filters (gravel and sand) and gravity-led reservoirs, and adoption of better hatchery design should be advocated based on one or two tanks, use of plastic incubators, punched pipes, and shelters;
- Since most hatcheries face the problem of high mortality during nursing stage, nursing ponds should be regularly cleaned and free from zooplanktons (predators) that prey on the seed stocks;
- In order to increase the breeding facilities and enhance total fish production per year, Government should promote and encourage farmers, especially those who are still starting nursery activities, to set up nursery ponds away from hatchery tanks and other nursing farms; and
- Extension services on fish hatchery operations should also be promoted in areas where water is sufficient or near water bodies.

Box 3. Long-term Recommendations

FiA should enhance its partnership with NGOs to obtain financial support for the conduct activities in the following aspects for sustainable freshwater aquaculture development of the country:

- Development of good quality and genetically-improved broodstocks;
- Promotion of cross-breeding schemes to avoid inbreeding, unplanned introgression and negative selection;
- Promotion of yearly partial replacement of broodstocks from adequate sources;
- Development of water infrastructures in rural areas especially those without irrigation canals and far from natural water bodies; and
- Promotion of the construction of large ponds (at least 4 m in depth) to serve as reservoirs so that water could be available even during the dry season.

production and market share, the short-term and long-term recommendations shown in **Box 2** and **Box 3**, respectively, should be taken into consideration.

References

Chin Leakhena. 2013. Assessment of Local Fish Seed Production in Takeo and Kampong Speu Provinces, Cambodia. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Aquaculture and Aquatic Resources Management, Asian Institute of Technology, Thailand; 135 p

Chin Leakhena. 2014. Mutual Partnership between Fish Hatchery Operators and Growers for Sustainable Aquaculture Development: A Case in Cambodia. *In*: Fish for the People Volume 12 Number 2: 2014. Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 14-23

CIPS. 2004. Cambodia Inter-Censal Population Survey (CIPS). National Institute of Statistics, Ministry of Planning, Phnom Penh, Cambodia

CSES. 2007. Poverty Profile and Trend in Cambodia. Findings from the 2007 Cambodia Socio-economic Survey (CSES). World Bank, June 2009; 131 p

Delahaye, Oliver G. 2002. Inland Fish Status in Southern Cambodia, Master's Thesis, Asian Institute of Technology, Bangkok, Thailand; 29 p

FAIEX. 2009. Impact Survey of the Freshwater Aquaculture Improvement and Extension Project (FAIEX), Fisheries Administration, Phnom Penh, Cambodia; pp 85-101

FAO. 2007. Assessment of freshwater fish seed resource for sustainable aquaculture. FAO fisheries Technical paper, Rome 2007; pp 145-169

FiA. 2009. Fishing for the Future. A strategic planning framework (SPF) for fisheries: 2009-2018, Produced by the Planning and Accounting Division of FiA. Draft version 7b – 30th April 2009. Fisheries Administration, Phnom Penh, Cambodia; pp 5-13

FiA. 2010. Background Information. The Strategic Planning for Frameworks, 2010-2019.Fisheries Administration, Phnom Penh, Cambodia; pp 20-31

FIA. 2012. Fisheries Statistics of Cambodia. Fisheries Administration, Phnom Penh, Cambodia

GPCC. 2008. General Population Census of Cambodia (GPCC). Cambodian Statistical Yearbook, National Institute of Statistics, Ministry of Planning, Phnom Penh, Cambodia

Hortle, K.G. 2007. Consumption and the Yield of Fish and Other Aquatic Animals from the Lower Mekong Basin. MRC Technical Paper No. 16, Mekong River Commission, Vientiane; 87 p

Index Mundi. 2014. Cambodia Demographic Profile 2014. CIA World Factbook, USA

JICA. 2009. Impact Survey of the Freshwater Aquaculture Improvement and Extension Project. SN Consultation Team, Phnom Penh, Cambodia

JICA. 2010. Poverty Profiles in the Asian Region. The final report for poverty profile, Phnom Penh, Cambodia; pp 2-4

Nam, So and Buoy Roitana. 2005. A Review of Inland Fisheries Management in Cambodia. The paper submitted to the international Seminar on Inland Fisheries Management, 21-26 September 2005, New Delhi, India. Department of Fisheries, Phnom Penh, Cambodia; 20 p

NCDD. 2009a. Basedth District Data Book 2009. National Committee of Sub-National Democratic Development, Kampong Speu, Cambodia; 7 p

NCDD. 2009b. Tramkak District Data Book 2009. National Committee of Sub-National Democratic Development. Takeo,Cambodia; 7p

NCDD. 2010. Commune databases. National Committee for Sub-National Democratic Development

Needham, Steve. 2011. Shining the Light on the Invisible Woman in Fisheries Development. ***In***: Fish for the People Volume 9 Number 1: 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 2-5

SEAFDEC. 2010. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2011. Fishery Statistical Bulletin of Southeast Asia 2009. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 149 p

SEAFDEC. 2012. Fishery Statistical Bulletin of Southeast Asia 2010. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 143 p

SEAFDEC. 2013. Fishery Statistical Bulletin of Southeast Asia 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 133 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2012. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

Sophearith, Nom. 2005. The Role of Fish in Food Security and Changing Consumption Patterns. An output from the DFID-funded Post-Harvest Fisheries Livelihood Project. Department of Fisheries, Phnom Penh, Cambodia; 65 p

Takeo Provincial Office. 2008. Profile of Takeo Province, Cambodia. Takeo, Cambodia

World Population Review. 2014. Population of Cambodia 2014. Population Reference Bureau, Washington D.C., USA

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Species Identification of Commercially Important Cephalopods of Thailand

Charuay Sukhsangchan and *Paphassawan Sunthornket*

Identification of commonly important species of cephalopods could be a gigantic task. However, a system to identify common species of cephalopods has been developed by turning to the morphological characteristics of their paralarvae. Paralarva is the stage after hatching or small size of aquatic species that usually looks similar with that of their parents. However, in some species of cephalopods the paralarvae could look differently from their parents, making it difficult to identify some species even at the genus or species level. It is in this regard that a study was conducted at Kasetsart University in Thailand with the objective of establishing the morphological characteristics of the paralarvae of cephalopods commonly found in the waters of Thailand as means of facilitating species identification at the paralarval stages of the species.

Cephalopods belong to Phylum Mollusca and are evolutionary in nature with long history of existence. Cephalopods are believed to have evolved from the earliest coleoids with internal shells to the Cambrian period when most had reduced or lost their shells up to the Jurassic period when modern species of coleoids (Subclass: Coleoidea; Class: Cephalopoda) had much reduced shells or completely lost their shells (Boyle and Rodhouse, 2005). Cephalopods usually lay eggs after fertilization of about one week or more.

Nabhitabhata (2009) reported that many cephalopods are abundant in the waters of Thailand with high biodiversity, and are reported to belong to 23 families, 43 genera and 80 species, which had been identified and classified from adult specimens. Based on Collins *et al*. (2002), the external morphology of paralarvae could be used in determining the distribution and abundance of cephalopod species noting also that knowledge of the morphology of paralarvae is important to fully understand the cephalopod's life cycle. It has therefore become necessary to compile information on the external morphological characteristics of the paralarvae of some species of cephalopods to better understand their life cycles, especially those commonly found in the waters of Thailand.

In Thailand, many cephalopods are commercially important and in the 2012 fishery statistical records, these species comprised about 8% of the country's total production from marine capture fisheries in terms of volume and about 19% in terms of value (SEAFDEC, 2014). In the Gulf of Thailand, it was reported that the Indian squid (*Photololigo duvaucelli*), mitre squid (*Photololigo chinensis*), bigfin reef squid (*Sepioteuthis lessoniana*), and cuttlefish (*Sepia* spp.) appeared dominant in the catch from squid jigging experiments conducted in 2013 (SEAFDEC/Training Department, 2013).

In the national and regional fishery statistical reports, cephalopods are classified as cuttlefish, bobtail squids *nei*, common squids *nei*, various squids *nei*, octopuses *nei*, and bigfin reef squid, implying that there are still considerable number of cephalopods that have not been identified at species level, and as a result, their production has been recorded only as *nei* (not elsewhere included). Considering the significant production volume reported under these categories, *e.g.* production of common squids *nei* reported by Thailand in 2012 was 74,282 metric tons, therefore it is necessary that the species level of such cephalopods should be identified in the future for the purpose of establishing the status and trend of their production and utilization at the regional level. An analysis of the case study carried out by the authors from Kasetsart University in Thailand indicated that identification of commonly important cephalopods could be facilitated through the morphological characteristics of their paralarvae, and suggested that this system could be useful as reference in similar endeavors.

The Case Study

In the case study, broodstocks of five species of commercially important cephalopods collected from the coastal waters of

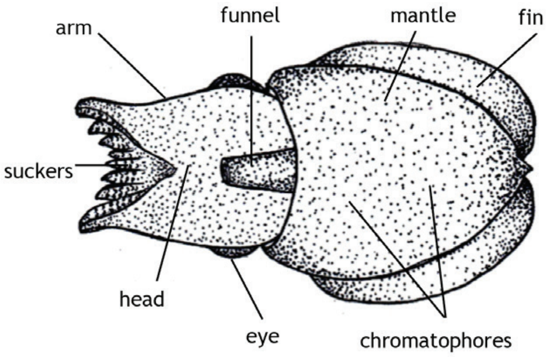

Fig. 1. External parts of paralarvae of cephalopods used for species identification

the Gulf of Thailand and Andaman Sea were reared and made to spawn at the laboratories of the Department of Marine Science, Faculty of Fisheries of Kasetsart University in Bangkok, Thailand. These are the bigfin reef squid (*Sepioteuthis lessoniana*), needle cuttlefish (*Sepia aculeata*), spineless cuttlefish (*Sepiella inermis*), Pharaoh cuttlefish (*Sepia pharaonis*), and marble octopus (*Amphioctopus aegina*).

After the paralarvae of the commercially important species had been collected from the spawned broodstocks, these were preserved in 10% formalin and put in 70% alcohol for observation. The external morphological characteristics of the paralarvae were then observed under stereo microscope and measured for their mantle length (ML) and head length (HL), while their arm pattern and characteristics of the suckers in each arms as well as the chromatophores (**Fig. 1**) were noted. Moreover, other distinguishing characteristics were also recorded and finally, the paralarvae were weighed accordingly. Furthermore, the morphological characteristics of the corresponding adult stages of the species were also observed as these could be used for verifying the species identified (**Fig. 2-6**).

Morphological characteristics of cephalopods that are of commercial importance in Thailand

The compiled information on the morphological characteristics of the paralarvae of common cephalopods shown in **Tables 1-5** would serve as useful reference for the identification of commercially exploited cephalopods, especially at species level. From the results of the analysis conducted on these common cephalopods, their morphological characteristics are summarized below which could be used in identifying the species of cephalopods at species level even at their paralarval stages.

Bigfin reef squid (*Sepioteuthis lessoniana*)

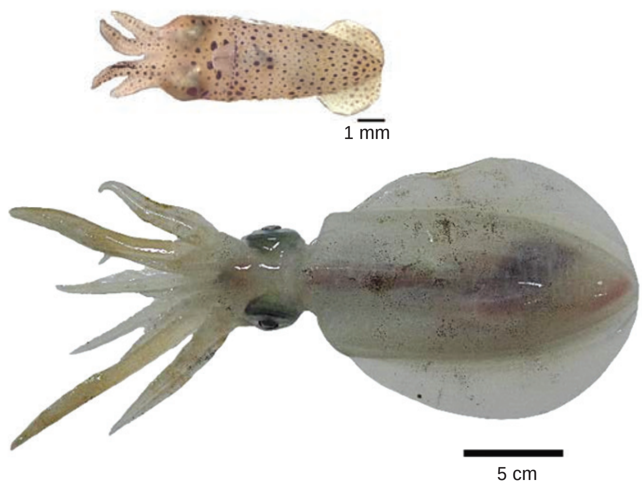

Fig. 2. Paralarva *(top)* and adult *(below)* of the bigfin reef squid

Table 1. Morphological characteristics of paralarva and adult of the bigfin reef squid

Bigfin reef squid (*Sepioteuthis lessoniana*)	Morphological Characteristics	
	Paralarva	Adult
Mantle	long and sharp at posterior, ave length of mantle (ML) = 6 mm	long and robust
Fins	semicircle in shape and medium in size, length = 40% of ML and width = 16% of ML	very large and with length over 90% of ML
Head	large, length (HL) = 43% of ML	large, narrower than the width of anterior part of mantle
Eyes	big, length= 60% of HL	large, more than 80% of HL
Funnel	short, length = 26% of ML	large, thick, length more than 90% of ML
Arms	formula is III>II>IV>I, length ranging from 17 to 42% of ML	formula is III>IV>II>I
Suckers	short-stalked and two rows in each arm	a largest sucker is present, almost one quarter of arm length from proximal end
Tentacular club	slightly expanded with four rows of suckers	slightly expanded with four rows of suckers
Chromatophores	spread throughout the body, head, fin and arm; pattern in each arm is straight line and at ventral side of head, pattern appears triangle in shape	spread throughout the body, head, fins and arms
Weight/ML	Weight: 0.0258 ± 0.0027 g	Max ML: 422 mm.

Needle cuttlefish (*Sepia aculeata*)

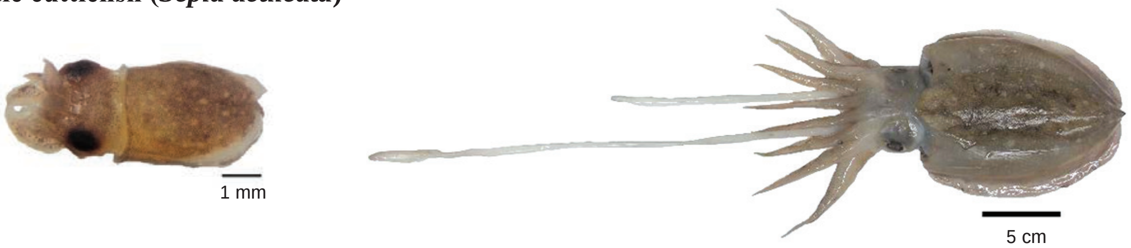

Fig. 3. Paralarva *(left)* and adult *(right)* of the needle cuttlefish

Table 2. Morphological characteristics of paralarva and adult of the needle cuttlefish

Needle cuttlefish (*Sepia aculeata*)	Morphological Characteristics	
	Paralarva	Adult
Mantle	broad and sac-like in shape, ave length = 3.69 mm	elongated-oval
Fins	narrow and long but less than mantle length, while posterior fin lobes are free and not connected at posterior end, length = 74% of ML and width = 17% of ML	thin and narrow, marginal and bordering the mantle, widest near posterior part
Head	large, length = 49% of ML	large, broader than length
Eyes	big, length = 58% of HL	moderately large
Funnel	long, length = 40% of ML	stout, conical, tapered at anterior
Arms	formula is I>IV>III>II, length = 22-43% of ML	formula is IV>III>II>I
Suckers	sub-equal in size, 2-3 rows on arm I-III and 4 rows on arm IV	large proximally and diminishing into smaller size at distal end
Tentacular club	small and short	with minute club suckers, sub-equal and arranged in about 10-14 longitudinal rows
Chromatophores	spread throughout body, head and arms but not on fins; more on dorsal side than on ventral side but size on latter is smaller, pale spots spread on dorsal side but not on ventral side	spread throughout the body, head, fins and arms
Weight/ML	Weight: 0.0205 ± 0.0013 g	Max. weight: 1.3 kg; Max. ML: 230 mm

Pharaoh cuttlefish (*Sepia pharaonis*)

Fig. 4. Paralarva *(left)* and adult *(right)* of the Pharaoh cuttlefish

Table 3. Morphological characteristics of paralarva and adult of the Pharaoh cuttlefish

Pharaoh cuttlefish (*Sepia pharaonis*)	Morphological Characteristics	
	Paralarva	Adult
Mantle	broad and sac-like in shape, ave. length = 7.1 mm	broadly elongated-oval, slightly pointed at posterior
Fins	narrow, long but less than length of mantle, posterior fin lobes are free and not connected at posterior end, length = is 71.42% of ML and width = 15.45% of ML	large, length is about 90% of ML
Head	large, length = 41% of ML; spine present at posterior end	large, slightly narrower than mantle opening

Table 3. Morphological characteristics of paralarva and adult of the Pharaoh cuttlefish (Cont'd)

Pharaoh cuttlefish (*Sepia pharaonis*)	Morphological Characteristics	
	Paralarva	**Adult**
Eyes	medium in size, length = 32% of HL	large
Funnel	medium in size, length = 30.72% of ML	large, stout and extends to interbranchial area of arm IV
Arms	formula is IV >I>III>II, length ranges from 18 to 47% of ML	formula is IV>III>II>I
Suckers	sub-equal in size, on arm I- IV arranged in 4 rows	equal in size
Tentacular club	broad	moderate in size, club suckers arranged in 6-8 transverse rows and 2 median rows, 5-6 of which are greatly enlarged
Chromatophores	spread throughout body, head and arms but not on fins, white spots present on ventral side along the mantle margin	spread throughout the body, head, fins and arms
Weight/ML	Weight: 0.0350 ± 0.0060 g	Max. weight: 5 kg; Max. ML: 420 mm

Spineless cuttlefish (*Sepiella inermis*)

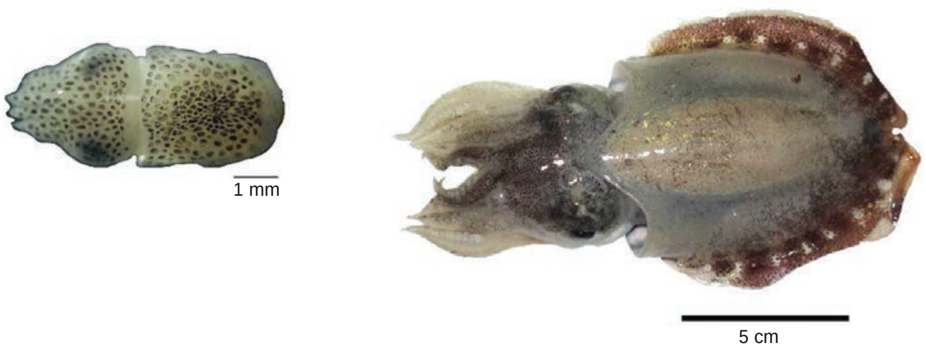

Fig. 5. Paralarva *(left)* and adult *(right)* of the spineless cuttlefish

Table 4. Morphological characteristics of paralarva and adult of the spineless cuttlefish

Spineless cuttlefish (*Sepiella inermis*)	Morphological Characteristics	
	Paralarva	**Adult**
Mantle	broad and sac-like in shape, ave length= 3.2 mm	elongated-oval, with pigment gland and pore present at posterior tip on ventral side
Fins	narrow, long but less than mantle length, posterior fin lobes are free, not connected at posterior end, length = 67.8% of ML, width = 20.6% of ML	narrow at anterior and slightly broader at posterior, length of which is about 90% of ML
Head	large, length = 69% of ML	moderately broad, slightly narrower than mantle opening
Eyes	medium in size, length = 42% of HL	large
Funnel	medium, length = 34% ML	short, conical, tapering at anterior, free in anterior half
Arms	formula is IV>I>II>III, length = 20.0-52.5% of ML	formula is IV>III>II>I
Suckers	sub-equal in size, 2 rows on arms I-IV and 3 rows on tentacular club	equal in size
Tentacular club	small and short	long, with minute club suckers and sub-equal in size
Chromatophores	spread throughout body, head and arms but not on fins, those on dorsal side are more than on ventral side but size on the latter is smaller, none on ventral side near posterior end	spread throughout the body, head, fins and arms
Weight/ML	Weight: 0.0119 ± 0.0010 g	Max. ML: 125 mm.

Marble octopus (*Amphioctopus aegina*)

Fig. 6. Paralarva *(left)* and adult *(right)* of the marble octopus

Table 5. Morphological characteristics of paralarva and adult of the marble octopus

Marble octopus (*Amphioctopus aegina*)	Morphological Characteristics	
	Paralarva	Adult
Mantle	short and oval in shape, ave length = 1.2 mm	elongated-oval to oblong
Head	medium, length = 56% of ML	small, slightly narrower than mantle
Eyes	very large, length = 95% of HL	moderate in size
Funnel	short, length = 33% of ML	long, tubular with slightly broad base
Arms	long and sub-equal in length, length = 66% of ML	moderately long about 2-3 times of ML, arm formula is III>IV>II>I
Suckers	sub-equal in size, only one row on each arm, each row contains 4 suckers, those close to buccal are smallest while those at middle arm are biggest	cup-like, typically biserial, normally large at the base
Chromatophores	spread throughout body, head and arms, number on dorsal side is same as on ventral side but are smaller on dorsal side than on the ventral side, appears triangle in shape in all arms and in zigzag pattern	spread throughout the body, head and arms
Weight/ML	Weight: 0.0030 ± 0.0005 g	Max. ML: 90 mm.

Discussion and Recommendations

Keys to the identification of cephalopods commonly found in the waters of Thailand based on their paralarvae are still not adequate (Jivaluk, 2001). Although in the past, many surveys and studies had been carried out, especially on the distribution and abundance of cephalopod paralarvae in Thai waters, many specimens could not be identified up to the species level. In 1995 and 1996, Jivaluk (2001) surveyed the Gulf of Thailand to determine the species, abundance and distribution of cephalopod paralarvae. Conducted in two periods, *i.e.* pre-monsoon in 1995 and post-monsoon of 1996, the survey collected samples using the oblique tow of bongo net. Specimens of the cephalopod paralarvae were identified to belong to 5 genera and 6 species, such as *Idiosepius* sp., *Sepiola trirostrata*, *Loligo* sp., *Abralia armata*, *Octopus* sp.1, and *Octopus* sp.2. Another survey on the distribution and abundance of cephalopod paralarvae in the Gulf of Thailand by Sukramongkol *et al*. (2013) from 14 March to 12 April 2013 using the M.V. SEAFDEC 2 collected samples that belong to only two families of cephalopods, *i.e.* Octopodidae and Enoploteuthidae. In addition, Thapthim (2002) reported that using the paralarvae of cephalopods collected from the South China Sea comprised 152 specimens classified into 20 species from 9 families. The most abundant were from the family Enoploteuthidae, Ommastrephidae, Octopodidae, Loliginidae, Cranchiidae, Sepiolidae, Octopodoteuthidae, Onychoteuthidae, and Gonatidae. Moreover, Sukramongkol *et al*. (2008) reported that cephalopod paralarvae were collected from the Bay of Bengal using the M.V. SEAFDEC from 6 November to 7 December 2008 using a pair of bongo net. The specimens were identified to belong to 13 families and 19 genera. Many of the specimens were found to belong to Family Ommastrephidae (41%) followed by Enoploteuthidae (14%) and Onychiteuthidae (6%).

Majority of individual species were identified as *Nototodarus hawiiensis* and *Abraliopsis* sp. Results from this case study could serve as reference in improving the means of identifying the species of cephalopods based on their paralarvae. Specifically, the chromatophores pattern, size and weight of hatching stage are the most important characteristics that should be observed and recorded as these information could be used during species identification (Okutani, 1965: Kubodera, 1991). The findings of Watanabe *et al*. (1998) could also be referred to during species identification, especially during the hatching stage or paralarvae of the diamondback squid, where the dorsal mantle is 1.4-1.6 mm long and chromatophores are scattered over the body, numbering about 190-230 on the dorsal side and about 220-320 on the ventral side. Yamamoto (1988) also reported that during the hatching stage of the pygmy cuttlefish (*Idiosepius pygmaeus paradoxus* Ortmann), ML is 1.0 mm long and HL is also 1.0 mm. However, such measurements are almost the same as those of the sharp-tail pygmy squid (*Idiosepius pygmaeus*) paralarvae found in the waters of Thailand as recorded at the laboratory facilities of the Department of Marine Science of Kasetsart University. Therefore, more efforts should be made to compile other morphological characteristics in order that correct and effective identification of common cephalopod species could be carried out.

Acknowledgment

The authors would like to thank the Department of Marine Science, Faculty of Fisheries of Kasetsart University in Bangkok, Thailand for the use of its laboratory facilities where the morphometric observations of the cephalopod paralarvae were made.

References

Boletzky, S.V. 2005. Idiosepius: Ecology, biology and biogeography of a mini-maximalist. Phuket Mar. Biol. Cent. Res. Bull. 66: 11-22 (2005); 25 p

Boyle, P. and P. Rodhouse. 2005. Cephalopods: ecology and Fisheries. Blackwell Science Ltd., Blackwell Publishing Company; 452 p

Collins, M.A., C. Yau, P.R. Boyle, D. Friese, and U. Piatkowski. 2002. Distribution of cephalopods from plankton surveys around the British Isles. Bulletin of Marine Science 71(1) 2002; pp 239-254

Jivaluk, J. 2001. Species, abundance and distribution of cephalopod paralarvae in the Gulf of Thailand in 1995 and 1996. Fish. Mus. Nat. Hist. Tech. Pap. No. 1/2001; 31 p

Kubodera, T. 1991. Distribution and abundance of the early life stages of octopus, *Octopus dofleini* Wulker, 1910 in the North Pacific. Bulletin of Marine Science, 49(1-2): 235-243

Nabhitabhata, J. 2009. Checklist of Mollusca Fauna in Thailand. Office of Natural Resources and Environmental Policy and Planning Bangkok, Thailand;576 p

Okutani, K. 1965. Studies on early life history of Decapodan Mollusca. I. A synoptic report on Rhynchoteuthion larva of *Todarodes pacificus* Steenstrup. Bull.Tokai Reg. Fish. Res.Lab., No.41; 21 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC/Training Department. 2013. TD/RP/176 - CRUISE REPORT ON RESEARCH ACTIVITY: M.V.SEAFDEC Cruise No. 93-2/2013 (14 March – 12 April 2013). Collaborative Research Survey on Fisheries Resources and Marine Environment of the Central Gulf of Thailand. Training Department, Southeast Asian Fisheries Development Center, Samut Prakan, Thailand; 67 p

Sukramongkol, N., R. Prommas and S.Promjinda. 2008. Distribution and abundance of cephalopod paralarvae in the Bay of Bengal. The Ecosystem-Based Fishery Management in the Bay of Bengal. Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand; pp 125-134.

Sukramongkol, N., S.Arnupapboon, P.Sunthornket and C.Sukhsangchan. 2013. Distribution and Abundance of Cephalopod paralarvae in the Gulf of Thailand. Report of Collaborative Research Survey on Fisheries Resources and Marine Environment of the Central Gulf of Thailand. Abstract; 27 p

Thapthim, N. 2002. Species Composition, Abundance and Distribution of Cephalopod Paralarvae in the South China Sea: Sabah, Salawak (Malaysia) and Brunei Darussalam Waters. Training Department, Southeast Asian Fisheries Development Center; 29 p

Watanabe, K., K. Ando, K. Tsuchiya and S. Segawa. 1998. Late embryos and paralarvae of diamondback squid *Thysanoteuthis rhombus* Troschel, 1857. Venus (Jap.Jour. Malac.). Vol.57, No.4:291-301

Yamamoto, M. 1988. Normal Embryonic Stage of the Pygmy Cuttlefish, *Idiosepius pygmaeus paradoxus* Ortmann. Zoological Science 5: 989-998

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Fishing Vessels Energy Audit: Operational Benchmarking of Fuel Consumption in Southeast Asian Trawl Fisheries – Pilot Project in Thailand

Bundit Chokesanguan, Steve Eayrs and *Suthipong Thanasarnsakorn*

Despite the increasing demand for fish and fishery products in view of their importance to human well-being, global fisheries production is at risk of falling off due to escalating and volatile fuel prices. Since the turn of the 21st century, the real global price of fuel has more than doubled and is characterized by unparalleled volatility. Rising fuel prices have also generally outpaced increases in fish prices (Gulbrandsen, 2012), making it difficult to offset this differential without landing more fish per unit of fuel consumed or reducing other fishing costs. Subsequently, the profitability of many fishers in Southeast Asia is under threat, jeopardizing the livelihoods of fishing families, communities, and others that directly rely on wild-caught seafood. The high consumption of fuel by the commercial fishing industry is also a concern because of its link to greenhouse gas emissions and climate change. According to Tyedmers *et al*. (2005), the global commercial fishing industry produces approximately 1.7 tons of greenhouse gas emissions for every 1.0 ton of live-weight seafood, and is responsible for over 1% of the greenhouse gas emissions from all sources combined. Starting in late 2013, FAO and SEAFDEC launched a Fishing Vessel Energy Audit Pilot Project in response to concerns on high and variable fuel costs, and associated greenhouse gas emissions from Thai commercial fishing industry. The project was aimed at evaluating fuel consumption in single-boat trawl fleet and identifying potential fuel savings through energy efficient fishing operations and practices. This Project also applied energy audits to trawlers in single-boat trawl fleet. It is envisioned that results of this pilot project could also be adapted in other countries of Southeast Asia to ensure that trawl fisheries is not only cost-effective but also environmentally efficient.

Fishing Vessel Energy Audit Pilot Project

The Training Department (TD) of the Southeast Asian Fisheries Development Center (SEAFDEC) in collaboration with the Food and Agriculture Organization of the United Nations (FAO) launched a Fishing Vessel Energy Audit Pilot Project in Thailand starting in November 2013. The Project surveyed the trawl fisheries in the Provinces of Chon Buri, Rayong, and Trat in the eastern Gulf of Thailand, and Prachaup Khiri Khan and Chumphon in the central Gulf of Thailand, to identify fuel-saving potentials through energy efficiency practices. Based on other experiences on fishing vessels energy audit and management plans, fishing vessels have the potential to reduce their energy use by 15-40% through improved efficiency. As envisioned, this pilot project on fishing vessel energy audit could provide a description of the energy usage patterns of fishing vessels for different operational phases and/or through a fishing season; potential energy saving measures together with expected payback periods; and measures of performance against recognized energy audit parameters, such as catch quantity per liter of diesel-fuel and fuel expense against catch revenue. Such information is necessary in order that fishing companies could undertake rational change towards energy saving practices and technologies. Furthermore, results of the fishing vessel energy audit could also address the concerns of the government sector as well as non-government organizations on the performance of the fishery sector as a primary industry, not only in terms of energy efficiency and viability but also its possible contributions to the increasing greenhouse gas emissions and carbon footprint.

The pilot project made use of the energy audit protocol based on a three-level audit process developed for Australian fishing vessels (**Box 1**). This process was designed to systematically collect data on fishing vessel design and operation, machinery specifications, and fuel consumption, in order that a prioritized, focused, and cost-

Map of Thailand

Box 1. Energy audit protocol used in the FAO-SEAFDEC Pilot Project on Fishing Vessel Energy Audit

Level 1: This audit process involves conducting consultations with fishers or trawler owners to estimate energy consumption, including annual and seasonal rates of consumption and associated costs. The required data are usually obtained through examination of their historical records or receipts, ideally during the past 24 months. Catch landings and value data is also compiled for the same corresponding period. These data can then be used to provide an initial assessment of peaks, troughs, and trends in energy consumed per unit of output, such as liters per hour or per kilogram of fish. This assessment provides a benchmark from which future energy consumption could be monitored, especially after the application of fuel saving technology or changes in operational behavior. Potential options to reduce fuel consumption may be identified at this time along with first order estimates of fuel savings; the accuracy of these estimates is likely to be ±40% of actual savings (Wakeford, 2010).

Level 2: This audit process usually involves a site visit to identify and view the sources of energy consumption. During this visit information on important vessel dimensions and specifications are collected. All sources of energy consumption are identified (*e.g.* diesel, lubricating oil, among others.) and machinery specifications, including rates of energy consumption, and usage patterns which also should be documented. At this time a list of applicable fuel saving options should be developed with estimated cost of installation, expected fuel-saving targets and annual savings, and payback periods based on knowledge of the vessel's operation. The accuracy of fuel saving estimates after completion of Level 2 should be ±20% of actual savings (Wakeford, 2010).

Level 3: This audit provides a detailed analysis of energy consumption, savings, and associated costs. Based on the outcomes of Level 2, this level focuses on critical areas that affect the energy efficiency of the fishing operation. At this level, a specialist may be required to carry out specific parts of the audit or to install metering or logging equipment to measure energy consumption over a variety of operating conditions. Identified fuel saving options may also be installed and their performance measured at this time. The outcome is a thorough evaluation of energy consumption and precise cost estimates for the implementation of energy saving options and their associated savings. Result of this analysis should be ±10% of actual savings (Wakeford, 2010).

effective effort could be made to reduce fuel consumption and greenhouse gas emissions. More specifically, the Project applied the Level 1 process as well as combined Levels 2 and 3 for convenience. While taking up the Level 1 process, 94 trawl fishers based in Chon Buri, Rayong, Trat, Prachaup Khiri Khan, and Chumphon Provinces were asked to accomplish a questionnaire that sought to obtain detailed information on five major aspects, *i.e.* trawler design, construction, condition, age, and maintenance schedule; design and specification of engine, transmission, propeller, and rudder; fishing gear design, specification, rigging, and operation; fishing trip characteristics, including duration, steaming and fishing times, impacts due to weather or damaged gear; and operating costs such as fuel, crew, food, lubricant, and ice.

Results of the Questionnaire Survey

In order to be consistent with the classifications used by the Department of Fisheries of Thailand, the responses of the trawl fishers were categorized into two aspects, namely: for trawlers less than 14 m in length, and trawlers that were larger. Analysis of the responses indicated that 65 fishers have been operating trawlers with overall length of less than 14 m, the volume of such trawlers ranged from 1 to 40 GT while engine propulsion ranged from 16 and 500 Hp, and no trawlers were equipped with auxiliary engine. The age of trawlers ranged from 6 months to 40 years, although trawlers between 5 to 10 years old were more common.

All trawlers were made of timber with service speed that ranged from 2 to 10 knots, propeller size ranging from 7 to 102 inches, and 90% of the fishers had been using four-blade propellers. The results also showed that over 80% of the fishers operate small trawlers and just less than 60% operate larger trawlers, while the fishers cited that fuel accounted for 50% or more of their total annual expenditures.

Results based on Level 1 audit

Although a small number of fishers did not or were unable to provide an estimate of the proportion of total expenditures that comprised fuel, the results suggested that the range of fuel expenditures for larger trawlers was 3,476,295 to 3,936,205 THB/year/trawler accounting for 36% to 86% of total expenditures. For small trawlers, the expenditures ranged from 1,452,211 to 1,647,257 THB/year/trawler which accounted for 34% to 73% of total expenditures. The average fuel cost for all trawlers accounted for just over 70% of the total expenditures (**Fig. 1**). On their fuel consumption per day or fishing trip, in an assumed 24-hr operation, the fishers also reported daily fuel consumption rate for all trawlers combined at 10.4 to 22.0 liters per hour.

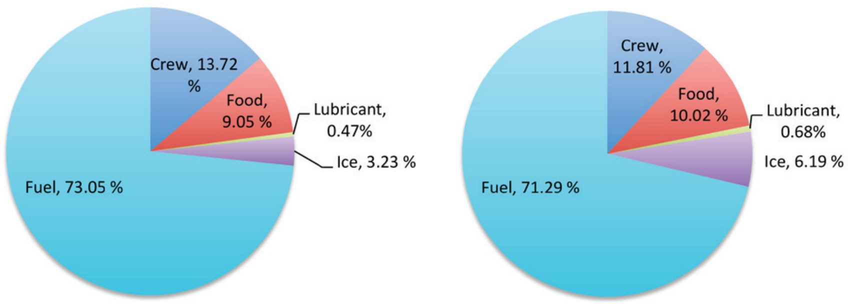

Fig. 1. Average expenditure of trawlers less than 14 m in length *(left)*, and trawlers 14 m or greater in length *(right)* based on responses of fishers using the Level 1 audit

Results based on Level 2 audit

Adoption of the next level of the audit process involved installing and using at-sea data collection equipment during the sea trials. Six trawlers were selected for this audit (**Table 1**), four of which were less than 14 m in length and the other two were 14 m in length or longer. Equipment were installed in the trawlers such as a fuel flow meter system, engine RPM tachometer, portable GPS to indicate trawler's location, heading, and speed, as well as a wind speed and direction indicator, and a vessel speed log. Small CCTV cameras were used to film the fuel meter, engine RPM, GPS, and activity on the back deck, the information of which was recorded on a 4 channel video recorded for subsequent review and analysis. The vessel specifications and machinery were also recorded.

For each trawler the relationship between fuel consumption and trawler speed was measured over a range of speed ranges and engine revolutions (rpms) during a 10-day period at sea. The result indicated that fuel costs were the dominant expenditures during the 10-day period for each trawler, accounting for 52-81% of total expenditures (**Fig. 2**). For five of the trawlers, labor costs were the second most dominant expenditure, although for one trawler the expenditure on ice was greater than that of labor. Income for the W. Yingcharoen was much greater than that of the

Table 1. General information of the six trawlers used for the Level 2 audit

Specifications	Name of Trawler					
	W. Yingcharoen	Chokepanthawee	Supsaitong	Chokenimitr	Chokchanapol	S. Charoenchai 1
Trawl type	Shrimp	Shrimp	Shrimp/fish	Shrimp/fish	Shrimp/squid	Shrimp/squid
Engine manufacturer	Gardner	Hino	Hino	Hino	Hino	Hino
Engine model	6LXB	EH700	EH700	H07D	H07D	EK100
Horsepower	180	130	168	180	190	275
RPM (steaming)	1000-1100	1200-1300	1400-1550	1700-1900	1400-1500	1300-1400
RPM (trawling)	1100-1200	1100-1200	1100-1200	1400-1500	1000-1100	1000-1100
RPM (idle/laying to)	700-800	700-800	700-800	700-800	700-800	700-800
Gearbox ratio	6:1	6:1	4:1	4:1	5:1	5:1
Length overall (m)	17	11.2	11	12	14.0	13.2
Length waterline (m)	16	10.4	10	11	13.0	12.2
Breadth (m)	4.6	3.7	3.7	3.7	3.6	3.1
Draft (m)	1.5~1.8	1.38	1.5	1.5	1.3	1.5
Fuel price (THB/l)*	25.52	29.96	29.96	29.96	23.00	23.00
Propeller dia.(inches)	50	44	38	39	42	52
Test period	14-24/10/13	6-16/11/13	14-24/10/13	6-16/11/13	23-31/11/13	23 - 31/11/13

*Price per liter of fuel paid by trawl fishers during the implementation of the project

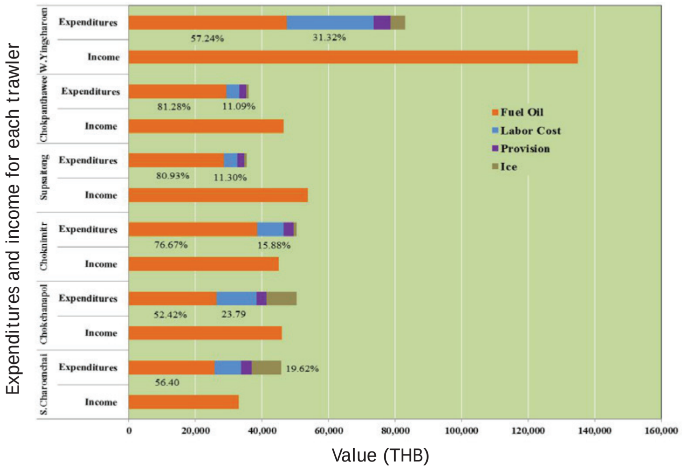

Fig. 2. Income and expenditures of trawlers in 10-day fishing trip, indicating the two most dominant expenditures proportionate to the total expenditures for each trawler

other trawlers due to its substantially higher landing volume and higher proportion of high-value species in the catch, such as blue crabs.

The fuel consumption data at free running speed from all 6 trawlers was collected over a range of rpm and speed in free running or steaming condition (with all fishing gear stowed onboard). In such a condition, there was substantial diversity between trawlers for a given engine revolution (**Fig. 3**). For example, at 1150 rpm the steaming speed of the **Choknimitr** was around 3.5 knots (kts) while the steaming speed of the **Chokchanapol** was around 6 kts. This may have been due to the differences in hull design and propulsion systems, although the influence of tide may also have been a contributing factor.

Meanwhile, the **W. Yingcharoen** and the **S. Charoenchai 1** were consistently the fastest trawlers based on the tested range of engine revolutions, while the **Choknimitr** was the slowest. At higher revolutions, the impact of reducing the rpms on steaming speed was relatively modest for all trawlers, compared to the same reduction at lower revolutions.

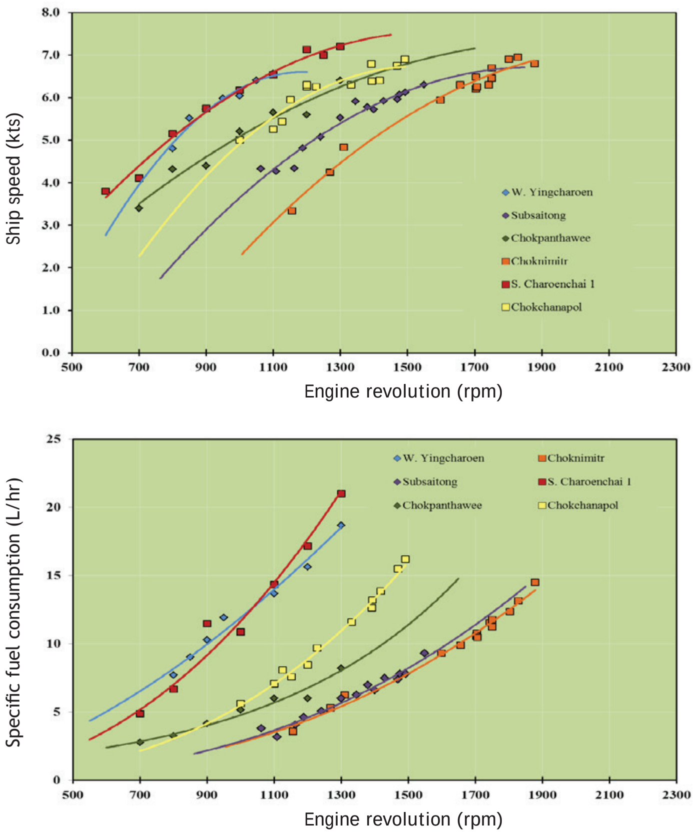

Fig. 3. Relationship between ship speed, fuel consumption and engine revolutions of vessels at free running (steaming)

More importantly, the collection of this data also permits an evaluation of the impact of trawler speed and rpm on fuel consumption. For example, a reduction in steaming speed from 7.0 kts to 6.0 kts resulted in an estimated fuel saving of approximately 40% while increasing the steaming time by a modest 14%.

Primarily in view of the concerns of fishers on the impact of data collection activities on their catch while trawling, fuel consumption data over a relatively narrow range of trawling speeds was collected from two trawlers only. Subsequently, the results only confirmed increased fuel consumption with speed but no further analysis could be made.

Discussion and Conclusion

This project represents the first known attempt to formally complete energy audits of Thai fishing trawlers. As a pilot project, testing new equipment and data collection and analysis protocols, and the results provide a benchmark to guide future efforts in this or other fisheries in Thailand or elsewhere in Southeast Asia. As part of the Level 1 audit process, it was observed that fishers do not keep accurate records of their expenditures. Many interviewed fishers only had a vague idea of the volume and cost of fuel

consumed each year, or the relative costs of other expenses such as food and ice.

This challenges the ability to review past fishing behavior, identify periods when fuel costs are highest, and hone in on remedial solutions. In Australia, the energy audit process ideally requires expense and catch reports over a 24-month period for this very reason. Site visits had enabled the compilation of important details and specifications of all 6 trawlers used in the audit based on Level 2, and the installation of metering and logging equipment. This was followed by at-sea data collection of energy and catch information on each trawler and an evaluation of the expenses and profitability of each trawler over a 10-day period. This period was an excellent opportunity to test sampling equipment under commercial conditions and develop the data collection protocol.

Initial assessment based on at-sea data collection indicated that judicious use of engine rpms is a key means for fishers to reduce fuel consumption. It also provides immediate fuel savings and requires no installation cost as many trawlers are already equipped with a tachometer. Another relatively inexpensive option is the installation of a fuel flow meter. In fisheries elsewhere, this meter is invaluable because it makes fishers acutely aware of the relationship between rpms and fuel consumption, and on how much fuel could be saved through modest throttle adjustments.

Way Forward

Analysis of the data compiled from this project would be continued with the objective of identifying, establishing and thoroughly evaluating the potential fuel saving options and protocols. The results would also include the time needed for fishers to pay back the acquisition and installation costs of fuel saving options (payback period) based on the collected data and the fuel saving potential of each option. Such an approach has been effectively used by Eayrs *et al*. (2012) to help prioritize a variety of fuel saving options by accounting for their relative contribution to fuel conservation and their purchase and installation costs.

A more extensive energy audit project with Thai fishing vessels has just been started using the knowledge and skills gained from this project. A follow-up project would therefore be carried out by SEAFDEC, making use of improved equipment and data collection protocols, and data collection to be conducted over a 6-month period. In this way, the data is expected to be more accurate and reflective of the fishing year and exhibit a better account of the impacts of the vagaries of tide and other severe environmental conditions.

References

Eayrs, S., T. Thorbjornson, J. Ford, H. Deese and G. Smith. 2012. Saving fuel to increase profitability and reduce environmental impact in a U.S. ground fish fishery. Presented during the 2nd International Symposium on Fishing Vessel Energy Efficiency, Vigo, Spain; 22-24 May 2012

Gulbrandsen, O. 2012. Fuel savings for small fishing vessels: A manual. Food and Agriculture Organization of the United Nations, Rome, Italy; 55 pp

Tyedmers, P. H., R. Watson and D. Pauly. 2005. Fueling global fishing fleets. Ambio 34: 635-638

Wakeford, J. 2009. Development and implementation of an energy audit process for Australian fishing vessels. Fisheries Research and Development Corporation, Project No. 2006/229; 177 p

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CALENDAR OF EVENTS

Date	Venue	Title	Organizer(s)
2015			
4-5 August	Sandakan, Malaysia	National Workshop on Sharks and Rays Data Collection in Malaysia	SEAFDEC/TD, MFRDMD and Secretariat
5-6 August	Singapore	Regional Technical Consultation on Harmful Algal Blooms in the ASEAN Region	SEAFDEC/MFRD
17-18 August	Cilacap, Indonesia	National Workshop on Sharks and Rays Data Collection in Indonesia	SEAFDEC/TD, MFRDMD and Secretariat
17–21 August	Philippines	Training Course on Catfish Hatchery and Grow-out Operations	SEAFDEC/AQD
19-21 August	Songkhla, Thailand	Experts Group Meeting on Development of the Regional Plan of Action for Managing Fishing Capacity (RPOA-Capacity)	SEAFDEC Secretariat
20-21 August	Puerto Princesa, Philippines	National Workshop on Sharks and Rays Data Collection in the Philippines	SEAFDEC/TD, MFRDMD and Secretariat
23 -28 August	Stockholm, Sweden	World Water Week	Sweden
24-27 August	Bali, Indonesia	Southeast Asia Regional Consultation Workshop on the Implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication	Indonesia
25-27 August	Davao, Philippines	2nd Working Group Meeting for the Joint Program on Tuna Research in the Sulu and Sulawesi Seas	SEAFDEC/TD
26-27 August	Singapore	End-Of-Project Meeting on Traceability Systems For Aquaculture Products in the ASEAN Region	SEAFDEC/MFRD
27-29 August	Bali, Indonesia	4th CTI-CFF Regional Business Forum	CTI-CFF
3-4 September	General Santos, Philippines	17th National Tuna Congress	Philippines
6-8 September	P. Sihanouk, Cambodia	National Workshop on Sharks and Rays Data Collection in Cambodia	SEAFDEC/TD, MFRDMD and Secretariat
10-11 September	Vung Tau, Viet Nam	National Workshop on Sharks and Rays Data Collection in Viet Nam	SEAFDEC/TD, MFRDMD and Secretariat
8 Sep-22 Feb 2016	On-line course	Distance Learning Course: Basic Principles of Health Management in Aquaculture	SEAFDEC/AQD
13-15 September	Semarang, Indonesia	2nd International Symposium on Aquatic Products Processing and Health 2015 (ISAPPROSH)	Indonesia
15-16 September	Bangkok, Thailand	Inception Workshop for the Oceans and Fisheries Partnership Project	USAID/Ocean project
14 to 18 September	Ulaanbaatar, Mongolia	29th Conference of the OIE Regional Commission for Asia	OIE
22-23 September	Denarau Nadi, Fiji	5th Regional Tuna Industry and Trade Conference - Pacific Tuna Forum 2015	INFOFISH
28-29 September	Trat, Thailand	5th Gulf of Thailand (GOT) Meeting	SEAFDEC-Sweden Project
5-9 October	Brasilia, Brazil	8th Session of the COFI Sub-Committee on Aquaculture	FAO
8-9 October	Vigo, Spain	20th anniversary of the FAO Code of Conduct for Responsible Fisheries	FAO
12-16 October	Philippines	Training Course on Catfish Hatchery and Grow-out Operations	AQD
2-5 November	Brunei Darussalam	8th RPOA Coordination Committee Meeting	RPOA-IUU
6-8 November	Qingdao, China	4th Annual World Congress of Aquaculture and Fisheries	WCAF
17-18 November	Bangkok, Thailand	9th Annual Meeting of ASEAN Fisheries Acoustic Society (AFAS)	AFAS
23-25 November	Philippines	38th SEAFDEC Program Committee Meeting (PCM)	SEAFDEC Secretariat & AQD
24 Nov-3 Dec	Philippines	Training Course on Community-based Freshwater Aquaculture for Remote Rural Areas of Southeast	SEAFDEC/AQD
26-27 November	Philippines	18th Meeting of the Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership (FCG/ASSP)	SEAFDEC Secretariat & ASEAN

Southeast Asian Fisheries Development Center (SEAFDEC)

What is SEAFDEC?

SEAFDEC is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia.

Mandate

To develop and manage the fisheries potential of the region by rational utilization of the resources for providing food security and safety to the people and alleviating poverty through transfer of new technologies, research and information dissemination activities

Objectives

- To promote rational and sustainable use of fisheries resources in the region
- To enhance the capability of fisheries sector to address emerging international issues and for greater access to international trade
- To alleviate poverty among the fisheries communities in Southeast Asia
- To enhance the contribution of fisheries to food security and livelihood in the region

SEAFDEC Program Thrusts

- Developing and promoting responsible fisheries for poverty alleviation
- Enhancing capacity and competitiveness to facilitate international and intra-regional trade
- Improving management concepts and approaches for sustainable fisheries
- Providing policy and advisory services for planning and executing management of fisheries
- Addressing international fisheries-related issues from a regional perspective


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AQD


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The second prize drawing winner, *Tok Sheng Sung*, from the national drawing contest in Brunei Darussalam

National Drawing Contests were organized in all ASEAN-SEAFDEC Member Countries as part of the preparatory process for the ASEAN-SEAFDEC Conferene on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" held by ASEAN and SEAFDEC in June 2011 in Bangkok, Thailand, in order to create awareness on the importance of fisheries for food security and well-being of people in the region.