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

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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

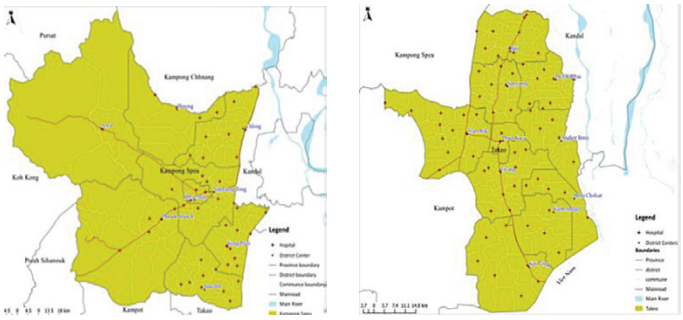

Fig. 1. Kampong Speu Province (*left*) and Takeo Province (*right*) in Cambodia

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

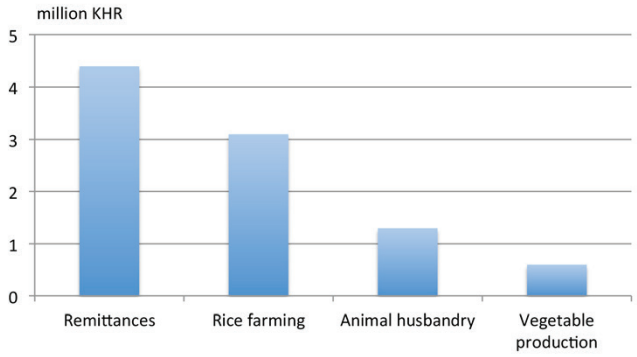

Fig. 3. Sources of other annual incomes of fish seed producers from Takeo and Kampong Speu in million KHR

Source: Adapted from Chin (2013)

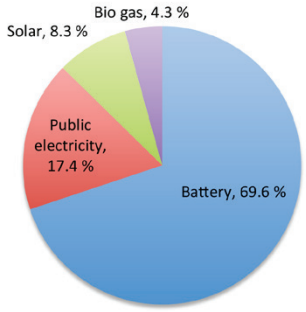

Fig. 4. Sources of fuel for fish hatchery operations in Takeo and Kampong Speu (n=23)

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

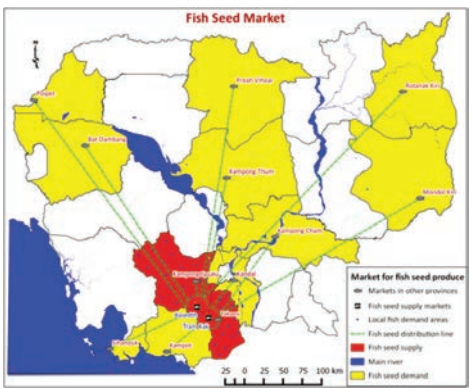

Fig. 5. Market of fish seeds produced in Takeo and Kampong Speu Provinces

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

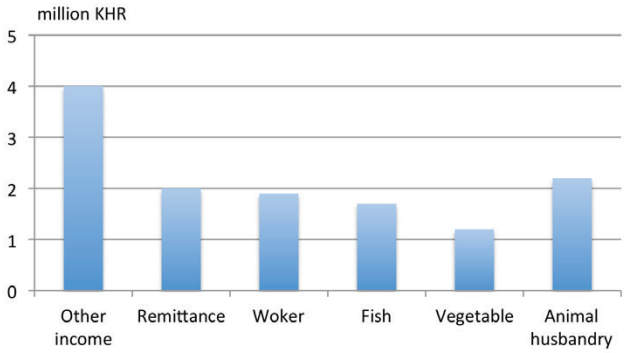

Fig. 6. Annual income of fish grow-out farmers (in million KHR) 1 USD = 4,000 KHR

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.

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