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"Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets"

Investigation 2 (07MNE01UC) - Phase 1

ASSESSMENT OF DIVERSITY AND BIOECOLOGICAL CHARACTERISTICS OF LOW VALUE/SMALL-SIZED FISH

Final Technical Report

So Nam[1], Leng Sy Vann[1], Prum Somany[1], Le Xuan Sinh[2], and Pomeroy Robert[3]
[1] Inland Fisheries Research and Development Institute (IFReDI), Fisheries Administration, Phnom Penh, Cambodia
[2] College of Aquaculture and Fisheries, Can Tho University, Can Tho, Vietnam
[3] University of Connecticut, USA

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Abstract
We defined inland small-sized fish species in lower Mekong River basin of Cambodia and Vietnam as species that generally has a maximal total length of equal to or less than 25 cm and a low market value, generally 5 to 10 times lower a market value of big-sized or commercially important fish species. The lower Mekong River basin of Cambodia and Vietnam was very rich in small-sized fish species diversity. In total, at least 200 inland small-sized fish species are found and identified. Many of these small-sized fish species were truly abundant in the region. The most abundant small-sized fish was Trey riel in Khmer or Cá linh ria in Vietnamese (mainly *Cirrhinus siamensis* and *C. lobatus*). Top ten small-sized fish species were also identified in both countries Cambodia and Vietnam. The proportion of small-sized fish species was more than 80% of the total inland fish catch. Of the total inland small-sized fish catch, juvenile of big-sized fish varied from 35 to 51%.

Aquaculture of carnivorous (including snakeheads) and omnivorous fish species in the lower Mekong River basin of Cambodia and Vietnam was highly dependent on inland fisheries of small-sized fish for sourcing key dietary nutrient inputs. The ban on snakehead farming in Cambodia seemed to be not effective as resources for implementation are lacking. The use of inland small-sized fish for snakehead farming in the Mekong Delta of Vietnam had both negative and positive impacts.

This study had very important implications for sustainable utilization and management of inland small-sized fish resource and for sustainable development of snakehead aquaculture in the lower Mekong River basin of Cambodia and Vietnam.

Introduction

The Mekong (Fig. 1) is the twelfth longest river in the world, the seventh longest river in Asia, and the longest river in Southeast Asia (Rainboth, 1996). It is born in the glaciers over 5,000 m above sea level in the Tibetan Himalayas, from where it flows through six countries (China, Myanmar, Laos, Thailand, Cambodia and Vietnam) for 4,880 km before it empties into the South China Sea in southern Vietnam. It has a drainage area of 802,900 km^2 and an average runoff of 475,000 million m^3 (Rainboth, 1996). As the Mekong passes into Cambodia it flows over the Khone Falls (the highest natural water fall, with an elevation drop of 21 m) and follows a nearly straight course with many stretches of rapids through eastern Cambodia. In eastern Cambodia (Kratie province), river flow records indicate that the seasonal discharge of the Mekong has a rainy season maximum to dry season minimum ratio of 53.6. This seasonal flow change is much more pronounced in the Mekong than in any other great river of the world (Welcomme, 1979). Between June and September/October, when the Mekong floods are rising in Chaktomouk (also known as Quatre Bras), the discharge is diverted into three branches: (1) the Mekong proper, also named Lower Mekong or Mekong *Krom* in Cambodian (which receives 62 to 68% of the flow; (2) Bassac River (receiving 12 to 14%); and (3) Tonle Sap (also named Great Lake) (receiving 11 to 23%).

Figure 1

The contribution of various ecotones to global biodiversity reaches in Southeast Asia the status of hotspot (Myers et al., 2000). The Indo-Burma region, including the Mekong River basin, is no exception (Kottelat, 1989; Rainboth, 1996). The aquatic resources of the basin represent an enormous biodiversity with an estimated 1,700 fish species (Cambodia harbours approximately 500 fish species) (Rainboth, 1996) and numerous other aquatic animals and plants. Its extremely diverse fish community reflects past climatic and geological processes, which have brought together the fauna of several river systems (Rainboth, 1996), and places the Mekong among the top three rivers in the world (after the Amazon and the Zaïre/Congo) (Dudgeon, 2000).

The number of endemic fish species is very high in the Mekong River basin (e.g. 28 species of Cyprinidae; 17 of Cobitidae) (So, 2005). The fish fauna comprises carps (Cyprinidae – 54%), catfishes (Pangasiidae, Siluridae, Clariidae, Schilbeidae, Bargridae, Sisoridae and Askydae – 19%) and murrels (Chanidae and Ophicephalidae – 8%). The remaining 19% consists of featherbacks (Notopteridae), herring (Clupeidae), climbing perch and gouramis (Anabantidae) and other miscellaneous groups.

Fish has long been critical to all Cambodians as well as other Mekong riparian countries. It is a major source of nutritious food in the daily diet, a primary source of income and has strong cultural and religious significance. Fisheries matter a great deal to the millions of people who live on the banks of the country's rivers, particularly those living in and around the Tonle Sap Great Lake. Cambodians are considered one of the highest per capita consumers of freshwater fish in the world. The recent study jointly conducted by IFReDI and MRC found that the average fish consumption rate is 52.4 kg per person per year, which is in the mid-upper level of world ranges of 15 – 90 kg per person per year (Hortle, 2007). Therefore fish provide 82.1% of the total animal protein intake for the population. Cambodia fisheries contribute 8 to 12% of the Cambodia's GDP accounting for 31 percent of the GDP contribution of the agriculture sector (Kurien et al., 2006). Fisheries from the Cambodia's Mekong River basin contribute over 80 percent of the total annual fish catch in Cambodia, being equal to approx. 450,000 tones. Its value range from US$ 250 million at the landing sites to US$ 500 at markets (So & Buoy, 2005).

Thousands of tonnes of low value or small-sized fish are caught along their migration route, from Tonle Sap up the Mekong River to Khone Falls, and into tributaries. By estimation, at least 16,000 tonnes was caught by only one commercial type of fishing gear (bag net or dai) during 2004 (Hortle et al., 2004), more than 30,000 tonnes during 2005, and recently (2008) its catch dropped to 12,000 tonnes (FiA, 2009). Moreover, fishing in the river systems and their wetlands is highly diverse, and over 150 fishing methods are employed to fish small-sized fish (Hortle et al., 2004). No national statistical data of the production of total small-sized fish (including species, size and composition) are available.

Cambodia aquaculture represents about 10% of the total inland fisheries production (So & Haing, 2007), while the Mekong delta in Vietnam approximately 20% (Phillips, 2002). They have expanded, diversified and intensified; their contributions to aquatic food production have increased gradually and potentially. They are highly diverse and consist of a broad spectrum of systems, practices and operations, ranging from simple backyard small, household pond systems to large-scale, highly intensive, commercially oriented practices. In Cambodia, over 70% of freshwater aquaculture production come from cage culture (total: 4,492 fish cages) operated in Mekong basin, including the Tonle Sap Great Lake (43%), Tonle Sap River (17%), upper stretch of the Mekong River (19%), lower stretch of the Mekong River (14%) and Bassac River (7%) (So & Thuok, 1999). It is entirely dependent on wild fish both as seed and feed (So Nam et al. 2005). In Vietnam, about 4,639 fish cages are operated in four Mekong delta provinces, especially in An Giang and Dong Thap provinces, while about 17,000 ha of earthen ponds are used for fish culture there. The most commonly cultured fish species in the Lower Mekong Basin of Cambodia and Vietnam are snakehead (*Channa micropeltes* and *C. striata*), pangasiid catfish (*Pangasianodon hypophthalmus*), hybrid clarias catfish (*C. btrachus x C. gariepinus*), and giant freshwater prawn (*Macrobrachium rosenbergii*). Aquaculture of carnivorous and omnivorous fish species is highly dependent on inland fisheries of small-sized fish for sourcing key dietary nutrient inputs (So et al., 2005).

The government of Cambodia put a ban on snakehead farming in May 2005 and the reasons for this were the potential negative impacts on wild fish populations from wasteful snakehead seed collection and on other fish species diversity, and also potential negative effects on poor consumer groups from decreased availability of low valued fish. The incentives for choosing snakehead before other fish species by fish farmers are strong, generating more than 10 times higher profits (personal information, 2007).

The specific objectives of this study are as follows:

- To assess the diversity of small-sized/low value fish in order to characterize these small-sized fish into different species, genus and family;
- To estimate the abundance and catches of small-sized/low value fish in order to determine the current status and trends of small-sized/low value fish in the total inland fish catch;
- To quantify the share of juvenile of commercially important fish species in total catch of small-sized fish in order to provide foundation for tailoring planning and management of inland fisheries;
- To assess impacts of the use of small-sized fish for aquaculture and ban on snakehead culture in Cambodia on socioeconomics of fish farmers and wild fish populations; and
- To provide wise recommendations to develop fisheries management strategies/actions for small-sized fish management in order to mitigate negative impacts at national and sub-regional levels.

Methods and Materials

The study comprised four interrelated parts: (1) Literature review and laptop survey (questionnaire) work; (2) Consultations and field survey; (3) Ground truthing; and (4) Data analysis to provide insight into more recent status of use of inland small-sized fish and impacts of use of small-sized fish for aquaculture the Lower Mekong River basin of Cambodia and Vietnam.

Literature reviews

The literature review involved compiling existing information on (1) broad categories of aquaculture and general fisheries; (2) Fisheries statistics (1990-2008), Mekong Fish Database (2003) and FishBase (2008); and (3) use of small-sized or low value fish in Cambodia, and other Mekong riparian countries, and in Asia (Annex 1). The secondary information combined with information from short consultations key informants was useful for developing questionnaires and small-sized fish photo books for field interviews, and for planning ground truthing activities (See the below paragraphs).

Consultations with key informants

In Cambodia, seven short consultations with key provincial fisheries officers, local authorities and fisheries communities were carried out in October and November 2008 in seven provinces: Kampong Cham, Kandal, Phnom Penh, Kampong Chhnang, Battambang and Siem Reap (Fig. 2) in order to collect general information on fish and fisheries, and aquaculture status. Afterward, similar consultations were conducted in three provinces of Vietnam: An Giang, Dong Thap and Can Tho (Fig. 2).

Figure 2

Full field surveys with fishers

Field surveys in Cambodia were conducted between December 2008 and March 2009 by interviews of 350 medium and large-scale fishers who are using different types of major fishing gears (e.g. cast-net, seine-net, encircling seine-net, deep drag-net/trawl, pair trawl, giant lift net, net fence system with pen/*bor*, bag-net/*dai*, and fishing lot/fence/barrage) to catch small-sized fish species in order to collect information of species diversity, catch, importance, and harvesting issues of small-sized fish resources, proportion of small-sized and big- sized fish, and proportion of juvenile of big-sized or commercially important fish species using three types of prepared standard semi-open questionnaires (Annex 2) and small-sized fish photo book (Annex 3). The questionnaires and small-sized fish photo book were developed by the Project. The field survey included seven Cambodian provinces: one, Kampong Cham province located on the upper Mekong River; one, Prey Veng on the lower Mekong River; two Kandal and Phnom Penh on Tonle Sap River; and three, Kampong Chhnang, Battambang and Siem Reap located on Tonle Sap Lake, covering all major river branches, with a distance of over 500 km (Fig. 2; Table 1). Each of the above provinces has its specific common fishing gears to catch small-sized fish, and interviews were carried out with fishers who are operating all types of specific common fishing gears in each province (Table 1). Similar field surveys were also conducted between February and March 2009 by interviews of 69 fishers in three provinces of An Giang, Dong Thap and Can Tho in Vietnam (Fig. 2) using a standard semi-open questionnaire (Annex 2).

Full field surveys with fish farmers

Aquaculture surveys were carried out in both Cambodia and Vietnam in order to understand impacts of the ban on snakehead culture in Cambodia, and status and impacts of use of small-sized fish for aquaculture in Vietnam using two types of standard questionnaires (Annex 4) and small-sized fish photo book, which were developed by the Project. The field surveys in

Cambodia were conducted by interviews of 203 fish farmers who used to culture snakehead before the ban and now are operating snakehead, pangasiid or hybrid catfish culture in cages and ponds between December 2008 and March 2009 in seven provinces: Kampong Cham, Kandal, Phnom Penh, Kampong Chhnang, Battambang and Siem Reap, while the surveys in Vietnam were conducted by interviews of 100 snakehead farmers between February and March 2009 in three major aquaculture Mekong delta provinces: An Giang, Dong Thap and Can Tho (Fig. 2; Table 1).

Ground truthing

In addition, two IFReDI fish biologists conducted fish species catch composition analysis and fish species identification, and took fish photographs in the grounds, where fishers using different types of fishing gears to catch small-sized fish species, which complement to the above field interviews. Fish identification and catch composition analysis was intensively carried out during the whole bag-net (*Dai*) fishing season along Tonle Sap River from November 2008 to February 2009. Each month fish sampling, identification and catch composition analysis was conducted for one week. Fish identification in the field or at IFReDI laboratory was based a few books available in the Mekong region, e.g. MFD (2003), Kottela (2001), Rainboth (1996), and Kottela et al. (1993).

Data analysis

Data were thoroughly and carefully analyzed using SPSS and Microsoft Excel. They included small-sized fish catch, small-sized fish species diversity, size of dominant small-sized fish species, price of small-sized fish, proportion of small-sized and big- sized fish, proportion of juvenile of big-sized or commercially important fish species, perceptions and impact of the ban, and impacts of use of small-sized fish for aquaculture on natural fish stocks and availability of small-sized fish for local consumption, and general problems for the farmers and fishers.

Results and Discussions

The total number of interviews made during the field study was 722 (419 fishers: 350 in Cambodia and 69 in Vietnam, and 303 fish farmers: 203 in Cambodia and 100 in Vietnam) (See Table 1). The number of interviews made in the different provinces was 80 in Kampong Cham, 80 in Prey Veng, 79 in Kandal, 80 in Phnom Penh, 80 in Kampong Chhnang, 74 in Battambang, 80 in Siem Reap, 50 in An Giang, 59 in Dong Thap and 60 in Can Tho.

Table 1

Small-sized fish and inland fisheries

Based on this study small-sized fish species generally had a maximal total length of equal to or less than 25 cm. They generally had a10.5-time lower market value than big-sized fish species. Therefore small-sized fish species are more acceptable by and accessible to the poor particularly in seasons of high production, which reflects the findings of Roos et al. (2007). Funge-Smith et al. (2005) defined low value fish as: "Fish that have a low commercial value by virtue of their low quality, small-size or low consumer preference. They are either used for human consumption (often processed or preserved) or used for livestock/fish, either directly or through reduction to fish meal/oil".

Small-sized fish catch

In Cambodia, inland fisheries are significant for local food security, household income, and export markets. Cambodia fishers operated at least 150 types of fishing gears (Hortle et al, 2004). Middle-scale fishers in Cambodia operated at least forty types of mobile fishing gears. Anybody can fish by these middle-scale fishing gears, but a license is required. Of which, the seven most common and popular fishing gears were selected for this study: cast-nets, seine-nets, encircling seine-nets, deep drag-nets/trawls, pair trawls, giant lift nets, net fence system with pens/*bor* in Tonle Sap and Mekong River basin and their floodplains. The average fish catch was 10.9 tones per fish in 2008 (Table 2). This figure was declined from 19.7 tones per fisher in 2001, representing a decline of approx. 45% since 2001. Small-sized fish was abundant in the catch. The average proportion of small-sized fish catch in 2008 was 87.5% of total fish catch by this type of fishers, while the big-sized fish catch was 12.1%. The trends of proportions of small-sized fish catch have increased since 2001, i.e. increasing from 79.7% in 2001, being an increase of about 10%. Of the small-sized fish catch, 38.3% was juvenile of big-sized or commercially important fish species. The trends of proportions of juvenile of big-sized fish have increased for the last eight years, i.e. increasing from 19.8% in 2001 (Table 2).

Table 2

Bag-net '*Dai*' or stationary trawl fishery is, by law, one of the large or commercial scale fisheries in Cambodia, which filters the current, and is typically 25-45 m wide and 100 m long (Fig. 3). The operation of commercial-scale bag-net fishery is subject to payment of annual fees. Dai fishery operates during receding floodwaters between October and March each year in Tonle Sap River to filter migratory fish species, particularly small cyprinids of the genus *Cirrhinus* (misidentified as *Henicorhynchus*; *Trey riel* in Khmer), migrating from the Great Lake floodplains, via Tonle Sap River, to the Mekong River. Within this timeframe, there are, normally, two peak migration periods, one being at the end of December or January and the other at the end of January or February each year. Each peak period lasts for 6 – 10 days before the full moon (Lieng, 2006). Based on this study the average fish catch was 133.5 tones per bag-net in the 2007-2008 fishing season (Table 3). The per bag-net fish catch have declined since 2000-2001 fishing season, i.e. a decline of about 36%. Of the total bag-net fish catch, 96.5% was small-sized fish species, while big-sized fish catch was 3.5%. This

proportion of small-sized fish catch increased from 90.3% in 2000-2001, while the big-sized fish proportion decreased from 9.7% in the 2000-2001 fishing season. Of total big-sized fish catch in the 2007-2008 fishing season, 84.7% was juvenile of big-sized fish, which increased from 75.8% in the 2000-2001 fishing season (Table 3).

Figure 3

Table 3

The other commercial-scale fishing operation in Cambodia is based on 'lots', fishing areas which are auctioned every two years. Large-scale fishing gears are only permitted in fishing lots, which can only be fished in the open season (October to May in most areas). Such gears include fences with traps, and barrages. Fences, up to several kilometers in length, are built across flooded areas or lakes to direct fish into traps (Fig. 4). Barrages are smaller gears that block a stream and direct fish into traps (Fig. 5). The average annual fish catch of fishing lot system was 336.5 tones per lot in 2008, decreasing from 553.9 tones in 2001 or a decrease of approx. 39% over the past 8 years (Table 4). Of the total fish catch, small-sized fish catch was 82.3%, while big-sized fish catch 17.7%. The figure of small-size fish catch increased from 73.8% in 2001 (being an increase of about 9%), while the figure of big-sized fish decreased from 26.2% in 2001(being a decrease of 9%). The proportion of fish catch of juvenile of big-sized fish was 32.4% of small-sized fish catch in 2008 and 27.5% in 2001, representing an increase of approx. 5% since 2001.

Figure 4

Figure 5

Table 4

Inland fisheries in the Mekong Delta of Vietnam was less significant compared to Cambodia's ones and to its aquaculture sector. The most common and popular fishing gears used in Vietnam were gill-nets, seine nets, and pair trawls. The two most common fishing grounds were floodplain rice-fields, and rivers and canals. Approx. 71% of fishers fished in floodplain rice-fields and 29% in rivers and canals. The average annual fish production was 4.2 tones per fish. The proportion of small-sized fish catch was 96.2% of the total fish catch, while the proportion of big-sized fish catch was 3.8% (Fig. 6). The proportion of fish catch of juvenile of big-sized fish was 51.3% of the total small-sized fish catch. There was a significant decline of small-sized fish catch by 58% between 2001 and 2008, and of big-sized fish catch by 63% between both years.

Figure 6

Small-sized fish species diversity

Small-sized fish species caught by middle-scale fishers in Cambodia

Middle-scale fishers in Cambodia used mobile fishing gears such as cast-nets, seine-nets, encircling seine-nets, deep drag-nets/trawls, pair trawls, giant lift nets, net-fence system with pens/*bor* to generally catch fish in Tonle Sap and Mekong rivers. At least 25 commonly dominant fish species were caught and identified into different genera and specific names (Table 5). Existing standard Khmer names were also given to these small-sized fish species.

All photos, English names and maximal total length of these small-sized fish species were found in Annex 3.

Table 5

Although it was very difficult to estimate catch composition of each small-sized fish species, and this was therefore not included. However, top ten small-sized fish species were determined and ranked based on dominant level of each of the top ten species (Table 6). Trey riel (*Cirrhinus spp.*, formally *Henicorhynchus spp.*) was the most dominant small-sized species in the catch of middle-scale fishers, and the second and third most dominant small-sized fish species were Trey linh (*Thynnichthys thynnoides*) and Trey khanhchrouk (*Yaasuhikotakia spp.*), respectively. The top ten small-sized fish species contributed more than 80% of the total small-sized fish catch by this type of fishers.

Table 6

Small-sized fish species caught by bag-net or Dai owners along Tonle Sap River in Cambodia
Based on three major sources of data and information (fishers' interviews, fish farmers' interviews and ground truthing: fish species identification) collected between November 2008 and February 2009, 111 fish species were identified. Of which, 59 species are small-sized fish (Table 7). All scientific and Khmer names of these 59 small-sized fish species were given in Table 7. Photos, common English names and maximal sizes of these small-sized fish species were found in Annex 3.

Table 7

The top ten small-sized fish species were determined and ranked based on dominant level of each of the top ten species (Table 8). Trey riel (*Cirrhinus spp.*) was the most dominant small-sized species in the catch (53% of total small-sized fish catch), and the second and third most dominant small-sized fish species were Trey khnang veng (*Labiobarbus lineata*, 15%) and Trey slouek russey (*Paralaubuca spp.*, 13%), respectively. Trey linh (*Thynnichthys thynnoides*) made 5% of the total small-sized fish catch, while Trey arch kok (*Systomus aurotaeniatus*) was 4% of the total small-sized fish catch. In brief, these top five fish small-sized fish species made up to 90% of the total small-sized fish catch of bag-net fishery along the Tonle Sap River.

Table 8

Small-sized fish species caught by fishing lot owners Tonle Sap and Mekong floodplains in Cambodia
40 commonly dominant small-sized fish species caught by fishing lot owners from Tonle Sap and Mekong floodplains were characterized into different genera, specific names and Khmer standard names (Table 9). Photos, common English names and maximal sizes of these small-sized fish species were found in Annex 3.

Table 9

Although it was very difficult to estimate catch composition of each small-sized fish species, and this was therefore not included. However, top ten small-sized fish species were determined and ranked based on dominant level of each of the top ten species (Table 10). Trey riel (*Cirrhinus spp.*) was the most dominant small-sized species in the catch of this type of large-scale fishers, and the second and third most dominant small-sized fish species were

Trey khnang veng (*Labiobarbus lineata*) and Trey khanhchrouk (*Yaasuhikotakia spp.*), respectively. This pattern is similar to the above ones. The top ten small-sized fish species contributed more than 75% of the total small-sized fish catch by this type of fishers.

Table 10

Small-sized fish species caught by fishers in the Mekong Delta of Vietnam

The main fishing grounds in the Mekong Delta were rice-fields, rivers and canals. This leads to at least five black or resident fish species (e.g. *Rasbora spp., Anabas testudineus, Trichogaster trichopterus, Trichogaster pectoralis* and *Pristolepis fasciata*), were among the top ten small-sized fish species identified in the Mekong Delta of Vietnam (Table 11). At least 70% of the total catch of small-sized fish was made up these top ten small-sized fish species. Similar to the above three cases, the most dominant small-sized fish species was Trey riel (*Cirrhinus spp.*). In total, at least 19 small-sized fish species were dominant in the catch of the Mekong Delta of Vietnam (Table 12). All photos, English names and maximal sizes of these fishes were shown in Annex 3.

Table 11

Among the top ten small-sized fish species identified in the Mekong Delta of Vietnam, four species (i.e. *Cirrhinus spp., Cyclocheilichthys armatus, Labiobarbus lineata,*and *Paralaubuca spp.*) were same as small-sized fish species identified in the three cases of Cambodia (Table 8, 9 & 10). Interestingly, seven of the top ten small-sized fish species (i.e. *Cirrhinus spp., Cyclocheilichthys armatus, Labiobarbus lineata, Osteochilus microcephalus, Paralaubuca spp.,Thynnichthys thynnoides* and *Yaasuhikotakia spp.*) were found all three cases of Cambodia (i.e. middle-scale fishers, large-scale bag-net owners and large-scale fishing lot owners).

Table 12

Based on the five sources of data and information collection (literature reviews, key informant consultations, fishers' interviews, fish farmers' interviews and ground truthing) in Cambodia and Vietnam, 200 small-sized fish species were characterized into different genera and species, with photographs (Annex 3). Furthermore, existing Khmer (Cambodian), Vietnamese and English (common) names were provided to these small-sized fish species. Maximal total length of each small-sized fish species was also provided. The number of small-sized fish species found in this study significantly differs from the one made by So et al. (2005) where only 62 small-sized fish species identified. The discrepancy between research objectives and methodologies (especially target group interviews: only fish farmers interviewed in So et al. 2005 study) of both studies can be partially explained by the weak correlation between both numbers of low value fish species found. A nonexclusive second explanation for this discrepancy may be related to different geographical (spatial) sampling scales, where sampling locations of So et al. (2005) was only in the lower Mekong basin of Cambodia. Although this study was more comprehensive compared to So et al. (2005) both studies identified *Cirrhinus spp*. (*Trey riel* in Khmer and *Cá linh rìa* in Vietnamese) as the most dominant fish species in the Lower Mekong River basin of Cambodia and Vietnam.

Price of small-sized fish

Table 13, 14 and 15 shows the trends of average, minimal and maximal annual price of inland small- and big-sized fish harvested by middle-scale fishers, large-scale bag-net owners and large-scale fishing lot owners in Cambodia. In general, small-sized fish had lower price or market value than big-sized fish in the three cases of Cambodia and similarly the case of

Vietnam (Table 16). The average price of small-sized fish was Riel 742 per kg or US$ 0.18/kg, while average price of big-sized fish was Riel 7,753 per kg or US$ 1.9/kg in Cambodia. In Vietnam, The average price of small-sized fish was Dong 4,990 per US$ 0.28/kg, while average price of big-sized fish was Riel 24,147 per kg or US$ 1.4/kg. In Cambodia, therefore the price of small-sized fish was averagely approx. 11 times lower than the price of big-sized fish; i.e. about 9 times reported by middle-scale fishers, 11.7 times reported by bag-net fishers, and 11.4 times by fishing lot owners, while in Vietnam the price difference between small- and big sized fish was approx. 5 times.

Table 13
Table 14
Table 15

All cases showed a significant increase in price of small- and big-sized fish over the past eight years. In the cases of Cambodia, there was an average increase of approx. 6 times in price of small-sized fish between 2001 and 2008, and a 3-time increase for big-sized fish, while there a 4-time increase in price of small-sized fish and a 2-time increase in price of big-sized fish. The main reasons for the increase in price of fish could be explained by the decline of capture fish production (See the section of small-sized fish catch) and strong demands of small-sized fish for both human food and animal, including fish, feed for both local and regional export markets (See the next section).

Table 16

Utilization of small-sized fish

Small-sized fish species were traditionally used for making *prahok* (fermented fish paste, Norng Chakriya, 2009, personal communication), which is a vital protein source and favorable ingredient for most of the Cambodian population, particularly the rural poor during the closed fishing season and at the end of the dry season when fish are not abundant (So et al., 2007). In the past two decades low, value fish are also utilized for feeding fish and other animals (Camber et al., 2008; Eldin-Lundgren et al., 2008; So et al., 2005; So & Nao, 1999). Figure 7 showed the flows and supplies of small-sized fish in Cambodia. 84% of total small-sized fish catch in Cambodia were used for human food consumption (fresh or processed); being 71% used in Cambodia and 13% exported to Vietnam and Thailand, while only 16% were used for animal (including fish) feeds. This potential problem could be an increasing export of LVF to Vietnam, which will lead to a net loss of LVF for the Cambodian people. This problem is also reported in the studies of Camber et al. (2008) and Eldin-Lundgren et al. (2008). Hence, small-sized fish used in Cambodia was 80%, and exported was 20%. It was difficult to quantify the amount of small-sized fish used for human food consumption in fresh and processed forms, and the amount of small-sized used for animal and aquaculture feed separately. Therefore this is not included. All above studies, excepting So et al. (2007), have not quantified the proportions of small-sized fish used for human consumption or animal feeds. So et al. (2007) quantified such proportions only from small-sized fish harvested from bag-net fishery along Tonle Sap River. The proportions are similar to this study.

Figure 7

In Vietnam, harvested inland small-sized fish were totally used in the country for both purposes human food and animal and fish feeds. Approx. 72% of the total small-sized fish catch was used for human food consumption, 15% for snakehead fish culture industry as direct feed, and 13% for direct animal feed.

Figure 8

Aquaculture and impacts of use of small-sized fish

Cultured fish species

In Cambodia, the most dominant fish species being cultivated was Trey pra (*Pangasianodon hypophthalmus*), followed by snakehead (*Channa micropeltes and C. striata*) (Table 17), although the ban on snakehead culture was enacted by the Ministry of Agriculture, Forestry and Fisheries in 2005. The third popular culture fish species in Cambodia was Trey andeng kart (The hybrid catch *Clarias batrachus* x *C. gariepinus*). This reflects the findings of So et al. (2005) that Trey pra, Trey andeng kart, and Trey chdor are also the most popular cultured fish species before the ban in Cambodia. The other two *Pangasius* catfish species, Trey pou (*P. lar*naudii) and Trey Khae (*P. conchophilus*) were also popularly used for cage culture in this study and also in So et al. (2005) study (Before the ban). The other fish species, excepting Trey tilapia, listed in Table 17 were also used for pond and cage culture in Cambodia before the ban. Trey tilapia, an exotic fish species not found in the study by So et al. (2005) before the ban, is now being cultivated by many farmers (Table 17). Possible reasons for this could be that tilapia culture technology is simple and that Trey tilapia is acceptable at local markets (Camber et al., 2008). After the ban, all cage farmers interviewed in Battambang province replaced giant snakehead by hybrid catfish, which is a hybrid between exotic and native fish species, due to its fast growing and acceptability at local markets. However, all interviewed cage farmers replaced giant snakehead (*Channa micropeltes*) with snakehead murrel (*Channa striata*) that fingerlings were imported from hatcheries in Vietnam.

Table 17

In Vietnam, the main culture fish species in the Mekong Delta of Vietnam were the giant snakehead Ca bong (*Channa micropeltes*) and the snakehead murrel Ca loc (*Channa striata*). Of 100 fish farmers interviewed, 83 farmers cultured the snakehead murrel Ca loc in ponds or cement tanks, while 17 farmers cultured the giant snakehead Ca bong in cages (Table 17).

Sources of fingerlings

Before the ban on snakehead culture 100% of snakehead seed, mainly the giant snakehead, were collected from the wild for stocking floating cages in inland waters (So et al., 2005). After the ban, most of snakehead seeds of both giant snakehead and snakehead murrel (79%) were imported from Vietnam, i.e. Vietnamese hatcheries where snakeheads have been domesticated for at least 10 to 20 years, while only 21% of the stocked seed in Cambodia were collected from the wild, mainly the giant snakehead (Figure 8). This finding indicates that the ban on snakehead does not stop the collection of snakehead seed from the wild. In Vietnam, all snakehead seeds of both giant snakehead and snakehead murrel were from local hatcheries, where domestications have been taken place for almost two decades.

Figure 8

Use of small-sized fish for aquaculture

Among 12 fish species cultured in Cambodia, only four carp species (Trey Kahae, Trey Chhpin, Trey proloung and Trey prual, 31%) were not fed on small-sized fish, but they were cultured with other *Pangasius* catfish species and tilapia in a polyculture cage system (35% of total number of cage culture farmers). The two snakehead species, hybrid catfish and Trey khya (*Hemibagrus wyckioides*) were completely fed on small-sized fish, while *Pangasius* catfish species and tilapia were fed on a mixture of small-sized fish and rice bran. This result is of great importance as it shows that the ban on snakehead culture does not stop the use of

small-sized fish as fish feed. The seven main inland small-sized fish species being used as fish feed in Cambodia were Trey riel (*Cirrhinus spp.*), Trey sraka kadam (*Cyclocheilichthys armatus*), Trey khnang veng (*Labiobarbus lineata*), Trey kros (*Osteochilus microcephalus*), Trey sloeuk russey (*Paralaubuca spp.*), Trey linh (*Thynnichthys thynnoides*) and Trey bandol ampil (*Clupeichthys aesarnensis*). See Table 6, 8 and 10 and Annex 3 for the details. This result is similar to the ones of Camber et al. (2008) and So et al. (2005). The majority of small-sized fish (87%) used for aquaculture in Cambodia were from inland fisheries in Cambodia, while during the closed and lean inland fishing season marine small-sized fish (13%) were supplements (Figure 9). Some Cambodian fish farmers reported that sometimes marine small-sized fish were imported from Vietnam, but it was difficult to quantify, and therefore it is not included.

Figure 9

In contrast, the Vietnamese snakehead aquaculture mainly depended on marine small-sized fish as fish feed (73%), while only 27% of freshwater small-sized fish were used for snakehead feed (Figure 10). Most of the Vietnamese farmers fed their snakeheads with freshwater small-sized fish caught in Vietnamese inland waters in the wet season (mainly in August – September). Most of Vietnamese snakehead farmers reported that they bought freshwater small-sized fish from Cambodia to feed their snakeheads during December – February when the fishing season in Cambodia is open and is the peak fishing period of freshwater small-sized fish along the Tonle Sap River (Please also see Figure 7). The seven main inland small-sized fish species used for feeding snakeheads in Vietnam were: Cá rô đồng (*Anabas testudineus*), Cá linh ria (*Cirrhinus spp.*), Cá linh (*Labiobarbus lineata*), Cá sặc bướm (*Trichogaster trichopterus*), Cá lòng tong (*Rasbora spp.*), Cá chốt (*Mystus vittatus*) and Cá rầm (*Puntius brevis*).

Figure 10

Impacts of the ban on snakehead culture in Cambodia

Impacts on household economy from the ban on snakehead farming

There was a major difference between the numbers of fish farmers that reported decreased, increased or no changed household economy after the snakehead ban (Fig. 11). Of 203 interviewed fish farmers, the majority (57 %) of farmers said that their net profit had decreased due to more expensive fish feed (small-sized fish, rice bran and others), less profits from the cultivation, increased competition with other fish farmers, more expensive labors and other difficulties e.g. fish diseases and the ban itself. The economy was better now for 25 % of the farmers, mainly because of increased income from farmed fish compared to five years ago or before the ban. A given explanation for the increased market price of cultivated fish was that the stock of wild fish had decreased but the demand for fish is still high; market price had increased both for wild fish and cultivated fish. The remaining 18 % of the farmers did not experience any change in their economy after the ban (Fig. 11). The pattern of change in household income in this study differs from the study by Camber et al. (2008). Type of interviewed fish farmers and surveyed locations selected might be the main explanation of this difference. In this study, of the total interviewed fish farmers, 157 farmers (77% of total number of interviewed farmers) had cultured giant snakehead before the ban (Table 18), while in the study by Camber et al. (2008) only 40% of the interviewed fish farmers had cultivated giant snakehead before the ban. Seven surveyed locations were selected in this study (Table 1; Fig. 2), while only four surveyed locations were selected for interviews in the study by Camber et al. (2008).

Figure 11
Of the interviewed 157 farmers who had cultured giant snakehead before the ban (Table 18), 127 farmers (81%) said that their profits decreased after the ban. The explanation given for this were a) giant snakehead could be sold at a higher market price due to traditional popularity of most Cambodians, b) the cost of fish feed (both small-sized fish and agriculture products) had increased after the ban, and c) the number of fish farmers had increased resulting in increased competition and lower prices of farmed fish. Another explanation put forward by some farmers was that rice bran now has to be bought to feed the fish. When giant snakehead was cultivated, the farmers, particularly cage farmers who are mostly also fishers, could themselves fish small-sized fish for free. Only 10 farmers said that their profits had increased after the ban. The reason for this was a diversified production (many different species reared together) that, according to the farmers, enabled them to sell the fish more easily. The other 20 farmers said that they did not experience any change in profits (or did not know), and some farmers said that they had compensated the income loss from not being able to farm snakehead with e.g. increasing the size of the cages or ponds.

Table 18

Of the total number of interviewed fish farmers, 68 farmers (33%) had continued snakehead culture after the ban on snakehead farming. Of which, 30 cage farmers in Siem Reap farmed snakehead murrel, while 38 farmers in Kampong Cham, Prey Veng, Kampong Chhang and Kandal farmed giant snakehead (Table 17). The main reasons for this were (1) snakehead farming was their traditional activity; (2) snakehead was a high market valued fish; (3) most of these farmers had no alternative livelihoods, and had no land for rice growing; and (4) most them were fishers who can harvest small-sized fish to feed their snakehead for free.

Impacts on availability of small-sized fish from the ban on snakehead farming
The observation or opinion of availability of small-sized fish was based on information from fishers they know or from own fishing activity. A majority (63 %) of all the fish farmers said they experienced a decreased availability of small-sized fish after the ban. The main arguments for this were that (1) many fishermen use illegal and disruptive gear when they fish (e.g. electric shocks, fine mesh sized or mosquito nets, pumping or draining fishing methods); (2) destruction of fish habitats (e.g. clearance of flooded forests); (3) that beside the high and increasing local demands, small-sized fish are increasingly being exported to other countries (i.e. Vietnam) for human food and animal/fish feeds (See also Fig. 7); and (4) increasing price of small-sized fish (See also Table 13, 14 & 15). Some farmers were negative to the ban and argued that they could not see any "result" (e.g. increase in availability of low value fish) and that only having a ban on just giant snakehead farming was not effective since the culture of Trey andeng kart also mainly depends of small-sized fish. Many farmers did not know or did not experience any change in availability of small-sized fish. These two groups represented together 21 % of the interviewed farmers. Some of the farmers (16 %, most of them were pond fish farmers), did, however, say they noticed an increased availability of small-sized fish after the ban as it would reduce fishing pressures on small-sized fish (Fig. 12).

Impacts on illegal collection of fish juvenile in the wild from the ban on snakehead farming
Collection of fish juvenile from the wild during the spawning (wet season) is illegal in Cambodia. The collected fish juvenile have been used for feeding snakeheads and other fish species before the ban on snakehead farming in Cambodia. The majority (78%) of the farmers said that illegal collection of fish juvenile from natural inland waters still exist after the ban (Fig. 13). The arguments for this were that (1) there are available local markets and export markets (e.g. Vietnam) for selling these fish juvenile for fish culture and animal raising; (2)

illegal fishing activity especially during the spawning season is increased due to loose implementation of fisheries law and other sub-laws; and (3) small-sized fish are expensive during this closed fishing or spawning season and alternative and good protein feed source for cultured fish and raised animals are fish juvenile. Some of the farmers (14%) did report that the ban is effective to prevent fishers from illegal harvesting of fish juvenile from Cambodia's inland waters during the spawning season. Only 8% of the interviewed fish farmers said they do not know (Fig. 13). This is the first assessment of such impacts due to lacks of this assessment in the study by Camber et al. (2008).

Figure 13

Impacts on collection of snakehead juvenile in the wild from the ban on snakehead farming

There are three main reasons that the Royal Government of Cambodia temporally banned on snakehead farming in 2005: (1) the potential negative impacts on wild fish population from wasteful snakehead seed/juvenile collection; (2) potential negative impacts on other fish species diversity from wasteful collection of fish juvenile; and potential negative effects on poor consumer groups from decreased availability of small-sized fish (MAFF, 2005). In this study the majority (73%) reported that the ban on snakehead farming in Cambodia is an effective solution to protect wild snakehead population. The main reason for this was that there is alternative source of snakehead seed/fingerling, which can be imported from Vietnam, and the hatchery snakehead seed grow faster than the wild one due to many generations of domestication breeding. However, this will impose new potential impacts on bio-security due to risks of importing disease carried snakehead seed (For details see the below section). Approx. 21% of the farmers said that the ban was not effective due to illegal snakehead farming, which still occurred e.g. in Champong Cham, Kampong Chhang, Kandal, Prey Veng and Siem Reap (See also Table 17). The observance of the ban is not complete and the control system in place seems subject to manipulation and bribery (Camber et al., 2008). Some of the farmers (6%) said they did not know the impacts of the ban on collection of snakehead juvenile as they have no experience in snakehead farming. This is the first assessment of such impacts due to lacks of this assessment in the study by Camber et al. (2008).

Impacts of the use of small-sized fish for snakehead culture in Vietnam

Impacts on fish species diversity and stocks from use of small-sized fish as direct snakehead feed

Snakehead aquaculture in Vietnamese Mekong Delta partially depends on inland small-sized fish as direct feed. Of total interviewed fishers (69 households) and snakehead farmers (100 households), the majority (72%) of these interviewees said that feeding snakeheads with inland small-sized had negative impact on fish species diversity, catch composition, natural fish stocks, and decreased fish catch (Figure 14). The main explanation for this were that (1) fishing pressures is increasing and over fishing; (2) illegal fishing gears (e.g. electric shockers and fine mesh nets) are intensely used in year round to catch all sizes of fish species including juvenile of large fish species; and (3) number of fishers is increasing. Some of the interviewees said that they did not know or this is a normal household activity for many households living in the Mekong Delta. Only 2% of the interviewees have got positive opinion of the use of small-sized fish as direct snakehead feed (Figure 14). The main argument was that inland small-sized fish including juvenile of large sized fish is nutritionally better feed than marine small-sized fish due to faster growth of their snakeheads when inland small-sized fish are fed.

Figure 14

Impacts on water quality from use of small-sized fish as direct snakehead feed
The majority (62%) of snakehead farmers experienced poor quality water in their snakehead culture ponds or tanks due to the use of small-sized fish as direct snakehead feed (Figure 15). This resulted in disease outbreaks and finally high mortality rate of snakehead was detected. Some of the farmers (35%), particularly cage snakehead farmers, do not know this problem and some of them reported that the above water quality problem is a normal problem as they could solve this problem by regular exchange of pond or tank water. About 3% of the farmers did, however, say they had never experienced poor water quality due to the use of small-sized fish as direct feed as they grew snakehead in floating cages.

Figure 15

Impacts on fish food security from use of small-sized fish as direct snakehead feed
Figure 16 shows the impacts of use of small-sized fish as direct snakehead feed on fish food security of the poor consumer groups in the Mekong Delta. The majority (81%) of fishers and snakehead farmers reported that there was a high competition between use of small-sized fish for direct snakehead feed and use for human food, particularly the food of the poor. Small-sized fish are not only important for food security of the poor but also they contain high nutritional values, particularly vitamin A, iron and calcium (Roos et al., 2007). Some of the farmers (7%) said that small-sized fish were better choice for fish feed, while big-sized fish and farmed fish were important for human food. Many fishers and snakehead farmers (12%) did not know the importance and the nutritional values of small-sized fish (Figure 16).

Figure 16

Impacts on farmers' household income from use of small-sized fish as direct snakehead feed
Approx. 75% of total snakehead farmers had good income generated from their snakehead farms, which mostly depended on small-sized fish as direct feed (Figure 17). This was the positive impact from use of small-sized fish for snakehead farming in the Mekong Delta. The main reason for this was that inland small-sized fish are seasonally available, while marine small-sized fish can be used for snakehead feed during the rest of the year. Furthermore, most of the snakehead farmers are living closed to inland waters such as rivers or many man-made canals, where provide good water and inland small-sized fish resources for their business. About 11% did not received good income from their snakehead farming activity as they faced with poor water quality and disease outbreaks. Some of the farmers (14%) had no ideas or did not want to tell about their household income (Figure 17).

Impacts on local job opportunity from use of small-sized fish as direct snakehead feed
Snakehead farming provided important job for local fish farmer groups and fishers. 85% of the interviewed fishers and farmers perceived positive impact of snakehead farming (Figure 18). The main explanation was that this activity can create good job opportunity for both local fish farmer and fisher communities to generate household income from snakehead farming and fishing, respectively. Some of the farmers (10%) got no ideas, while 5% perceived negative impact on job creation from snakehead farming. The main reason for this was that snakehead farming in the Mekong Delta of Vietnam are mostly depend on abundant marine small-sized fish as direct feed.

Figure 18

Conclusions and Recommendations

The lower Mekong River basin of Cambodia and Vietnam is very rich in small-sized fish species diversity. In total, at least 200 inland small-sized fish species are found and identified, in this study, and their photographs are available and attached. Many of these small-sized fish species are truly abundant. Trey riel in Khmer or Cá linh ria in Vietnamese (mainly *Cirrhinus siamensis* and *C. lobatus*) is the most abundant inland small-sized species in the lower Mekong River basin of Cambodia and Vietnam. The top ten small-sized fish species detected in the Mekong River basin in Cambodia are: Trey riel (*Cirrhinus spp.*), Trey srakar kadam (*Cyclocheilichthys armatus*), Trey khnag veng (*Labiobarbus lineata*), Trey kros (*Osteochilus microcephalus*), Trey slouek russsey (*Paralaubuca spp.*), Trey linh (*Thynnichthys thynnoides*), Trey kanhchrouk (*Yaasuhikotakia spp.*), Trey bandol ampil (*Clupeichthys aesarnensis*), Trey khampleanh phluk (*Trichogaster microlepis*), and Trey changwa (*Rasbora spp.*). These species make up to approx. 80% of total inland small-sized fish catch. In the Mekong Delta of Vietnam, the top ten small-sized fish species are Cá linh ria (*Cirrhinus spp.*), Cá linh (*Labiobarbus lineata*), Cá thiểu (*Paralaubuca spp.*), Cá rầm (*Puntius brevis*), Cá ba kỳ (*Cyclocheilichthys armatus*), Cá lòng tong (*Rasbora spp.*), Cá rô đồng (*Anabas testudineus*), Cá sặc bướm (*Trichogaster trichopterus*), Cá sặc rằn (*Trichogaster pectoralis*) and Cá rô biển (*Pristolepis fasciata*). These species contribute at 70% to the total inland small-sized fish catch. The estimate of inland small-sized fish catch in Cambodia is approx. 85% of the total inland fish catch, while the estimate in Vietnam is around 96%. Of the total inland small-sized fish, in Cambodia 35% are juvenile of big-sized or commercially important fish species, while in Vietnam 51%.

Inland small-sized fish species generally has a maximal total length of equal to or less than 25 cm and a low market value, generally 5 to 10 times lower the market value of big-sized fish species. Therefore inland small-sized fish species are more acceptable by and accessible to the poor particularly in seasons of high production. All inland small-sized fish species in the lower Mekong River basin of Cambodia are not "trash" fish, and all are eaten by human. Some inland small-size species have a high market value, e.g. Trey linh, Trey kanhchrouk, Trey kros. They are either used for human consumption (often processed or preserved) or used for livestock and fish, either directly or through reduction to fish meal or oil.

The ban on snakehead farming in Cambodia seems to be not effective as resources for implementation are lacking. Therefore, the ban has its following negative impacts: (1) decreased fish farmers' household income/economy, (2) decreased availability of inland small-sized fish in the country and exportation of inland small-sized fish to neighboring countries, e.g. Vietnam, (3) increased illegal collection of inland wild fish juvenile during the spawning season used as direct feed for fish farming and animal raising in the country as well as in Vietnam, (4) importation of disease carried snakehead seed from hatcheries in Vietnam for stocking in cages and ponds in Cambodia. Last but not least, approx. 45% of market-sized snakeheads sold at local markets are imported from Vietnam due to high and increasing local market demands resulted from population growth. However, the ban also has its positive impact; i.e. there is a decrease in collection of snakehead seed/juvenile from the wild due to availability of alternative snakehead seed/fingerling imported from Vietnam.

The use of inland small-sized fish for snakehead farming in the Mekong Delta of Vietnam has both negative and positive impacts due to no availability of commercial feed for snakehead. The negative impacts include (1) increased fishing pressures and over fishing by use of illegal fishing gears; (2) poor water quality and disease outbreaks faced by majority of snakehead farmers; and (3) high competition between use of inland small-sized fish for snakehead farming and use for human food (i.e. decreased availability of inland small-sized fish for the poor consumer groups). The positive impacts of use of inland small-sized fish for snakehead

farming include (1) generation of household income for a huge number of local snakehead farmers; and (2) provision of good job opportunity for snakehead farmers and fishers who are owning no or small land for making alternative livelihoods.

The following recommendations are proposed for sustainable management of inland small-sized species and conservation of juvenile of commercially important fish species and for sustainable snakehead aquaculture development in the lower Mekong River basin of Cambodia and Vietnam:

- To develop a national strategy for sustainable use of inland fisheries resources, particularly for the poor consumer groups;
- Promote regional cooperation among the countries in the lower Mekong River basin in order to get proper management of the inland small-sized fish resource due to that large population groups, particularly in Cambodia, are depend on small-sized fish as a free protein and also as a health provider;
- Provide sufficient physical and financial resources and incentives to fisheries officers in order to enforce law and legislations regarding prohibition of use of illegal fishing gears, especially fine-meshed nets and electric shockers to avoid collecting juvenile of commercially important fish species and fish breeders during the closed fishing or spawning season;
- To study impacts of common and most effective types of fishing gears in order to assess their fishing efforts and efficiencies, which will be useful to provide fishing quota;
- T introduce appropriate issues relating to status and utilization of inland small-sized fish to major stakeholders including decision markers, fishers, and consumers and at primary, secondary and tertiary educational level;
- To assess natural stocks of small-sized fish in order to imply for sustainable harvesting and utilization of small-sized fish in the lower Mekong River basin;
- To improve post-harvest handling and processing technologies to add values to small-sized or low value fish, combined with good hygiene and quality, in order to maximize utilization of small-sized or low value fish for human consumption rather than to be used as sources for fish and other animal meal;
- To establish a snakehead domestication breeding and weaning, with formulated feed, program in Cambodia to reopen the temporal ban on snakehead farming in order to develop a sustainable snakehead aquaculture in Cambodia, which will imply for sustainable utilization of inland small-sized fish;
- To improve regional and national capacity for nutrition research and research into nutrition requirements for carnivorous fish species, including snakeheads;
- Developing alternative feeds (e.g. non-fish protein diets) for weaning and growing snakeheads to reduce or replace the dependence of small-sized fish.
- To involve private sector to formulate and improve commercially manufactured feed for snakehead aquaculture; it can be better integrated into local economy with less import of ingredient, and be market at a lower price;
- To Raise awareness of advantages and disadvantages of pellets and formulated diets and small-sized fish;
- To analyze water quality and pathogenic agents of snakeheads in order to sustain snakehead aquaculture in Mekong Delta of Vietnam;
- To train snakehead farmers on improving farm-made feeds, feed and feeding strategies, benefit of using artificial diets, and monitoring and control of snakehead diseases outbreaks; and
- Research into consumer preferences for snakehead raised from pellet and small-sized fish.

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