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# Fishery and Aquaculture of Juvenile Mudskipper *Pseudapocryptes elongatus* (Cuvier, 1816) in the Coastal Zone of Mekong Delta, Vietnam

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## Abstract

Mudskipper (*Pseudapocryptes elongatus*) has become a high value species (US$ 8 $kg^{-1}$ in June 2008) in the markets of Mekong Delta, Viet Nam. This leads to high pressure on its fishery and increasing interest on its aquaculture. An investigation was conducted on 40 juvenile fishermen and 72 mudskipper farmers in Soc Trang and Bac Lieu provinces of the Mekong Delta from May to December 2006. The *P. elongatus* juveniles fishing activity started in 2001 in the study areas. Collection of juveniles is conducted in spring tide periods from May to November. Juvenile collecting nets are set along the coast and interior river sites. The mesh size of net is 1 mm (body net) and 0.5 mm at cod end. Mean CPUE was 200,466 ind $net^{-1}$ in 6 months period. The juvenile catch is supplied to mudskipper farms, stocked at 16.2 ind $m^{-2}$ in semi-intensive and 95.7 ind $m^{-2}$ in intensive farms and fed local commercial feeds. Farming period is from May to December. Yields were 6.4 ton $ha^{-1}$ in intensive and 0.8 ton $ha^{-1}$ in semi-intensive farms. Production cost and net profit were US$ 8,696 $ha^{-1}$ and US$ 12,784 $ha^{-1}$ for intensive farms; and US$ 967 $ha^{-1}$ and US$ 1,039 $ha^{-1}$ for semi-intensive farms. Mudskipper aquaculture has potential for coastal aquaculture development and is an alternative to shrimp farming in the Mekong Delta.

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## Introduction

The mudskipper (*Pseudapocryptes elongatus*) inhabits the mudflats of estuaries and tidal zones of rivers in India, China and the Mekong Delta of Vietnam (Rainboth 1996) and is one of the 34 species of oxudercine gobies known to be distributed from East to West Africa, South Pacific islands and Northern Australia (Murdy 1989). Mudskippers are euryhaline, air-breathing and amphibious species that live on mudflat areas, which imposes environmental challenges by tidal oscillations, extreme shifts and habitat conditions (Ishimatsu et al. 2007).

Almost ten years ago, the mudskipper has been considered to have little economic value in Asian countries (Takita et al. 1999). However, in recent years, China has become successful in seed production and farming the mudskipper (*Boleophthalmus pectinirostris)* in monoculture and polyculture systems in earthen ponds, with production from 750 to 975 kg $ha^{-1}$ (Hong and Zhang 2004). Around 13,000 ha were used for *B. pertinirostris* farming in China (Hong et al. 2007).

In Vietnam, the mudskipper *P. elongatus* is a high value species (US$ 4 $kg^{-1}$ in 2007 and US$ 8 $kg^{-1}$ in June 2008) and has high potential for coastal aquaculture in the Mekong Delta. *P. elongatus* aquaculture has developed rapidly to supply the high demand of domestic consumers. However, seed production has not succeeded yet in Vietnam. Therefore, wild seed supply of this species faces high catch pressure in the coastal provinces of the Mekong Delta. This issue raises great concern on the decline of this fish resource in the future. At present, information on juvenile fishery and aquaculture of *P. elongatus* has not been well reported yet. Thus, this study was conducted to provide scientific information on (i) fishing status and catch per unit effort of *P. elongatus* juveniles; (ii) existing mudskipper culture systems and its yields and economics; and (iii) constraints of these farming systems, in order to propose strategies for fishery resource management and aquaculture development for this species.

## Materials and Methods

A survey was conducted in the Bac Lieu and Soc Trang provinces of the Mekong Delta from May to December 2006. Bac Lieu and Soc Trang provinces are the first and second provinces that started *P. elongatus* wild juvenile collection and culture in the coastal areas of the Mekong Delta (Fig. 1).

The sample size for the survey was determined using the formula suggested by Yamane (1967). The sample sizes of juvenile fishermen and mudskipper farmers were calculated at 90% confidence level with precision e = ±10%.


**Fig. 1.** Study areas in Bac Lieu and Soc Trang provinces in Mekong Delta, Vietnam.

According to estimates by the Department of Fisheries in both provinces, the total number of local fishermen is about 50 households in Soc Trang and 110-120 households in Bac Lieu; and about 50-60 mudskipper farmers in Soc Trang and 170-180 farmers in Bac Lieu in 2006. There are no official report and statistical data on mudskipper juvenile fishermen and farmers in these provinces in 2006. These activities are new in the coastal provinces of the Mekong Delta.

Based on the following equation, the sample sizes were calculated and shown in the table below:

$$\mathbf{n = N/(1 + N*e2)}$$

where; n: sample size (people); N: total of people; and e: precision (10%)

| | Total number | Sample size |
|---|---|---|
| Fishermen | 165 | 62 |
| Farmers | 240 | 70 |

For fishermen, although the sample size should be more than 62 fishermen, actual field survey did not meet the required number because juvenile fishing is an illegal activity, thus, fishermen were not willing to be interviewed and other fishermen could not be located. Therefore, a total of 40 fishermen were interviewed in both provinces in this study.

Regarding mudskipper farmers, sample size should be more than 70 farmers. Actual number of respondents in this study was 72 farmers in both provinces, meeting the sample size requirement.

Rapid Rural Appraisal (RRA) technique (Townsley 1996) was used for the initial stage of this study. Structured questionnaire was prepared and pre-tested before actual interviewing of respondents. Besides, secondary data was also collected from the Departments of Fisheries of Bac Lieu and Soc Trang provinces.

# Results

### *Juvenile catch*

The juvenile fishing activity on *P. elongatus* started in 2001 in Bac Lieu province and in 2005 in Soc Trang province. According to the estimates of the Department of Fisheries, there are about 165 fishermen in both provinces in 2006. There were no statistical data on the number of fishermen in the two provinces, because mudskipper juvenile fishing has been a new activity in the coastal area of the Mekong Delta. In addition, local fishermen estimated that there were around 400 *P. elongatus* juvenile fishermen in the whole study area, each fisherman having 1 to 2 bag-nets. The number of outsider fishermen could not be estimated and thus were not included in this study. There were several conflicts among mudskipper juvenile fishermen communities particularly on the use of the fishing ground of *P. elongatus* juveniles. In addition, this activity caused another conflict because of obstruction to river transportation.

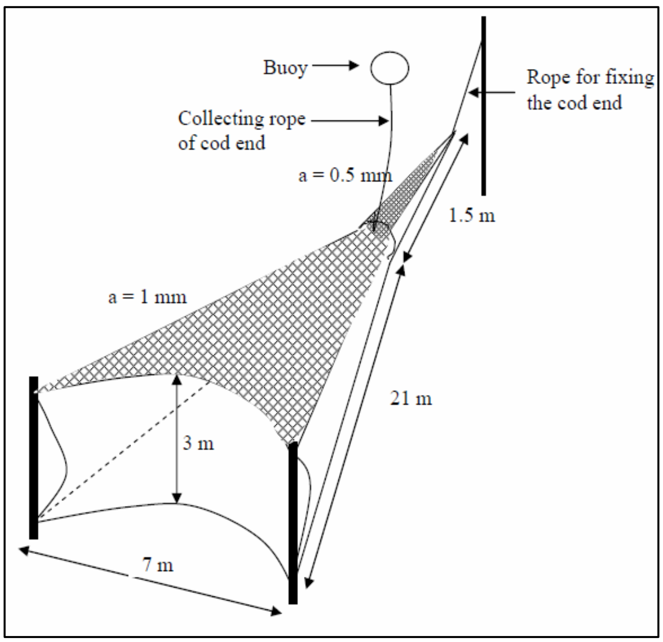


**Fig. 2.** The design of bag-net used to catch mudskipper *Pseudapocryptes elongatus* juveniles in the Mekong Delta, Vietnam.

The average size of bag-net is 7 m wide, 3 m high and 21 m long (Fig. 2). The mesh size of the net is 1 mm at the open part, 0.5 mm at the cod end (1.5 m long). The catch season is from the end of May to December, that includes 12 days per month during the spring tide of new and full moon periods. The fishing activity is conducted when high tide comes at night and daytime. Each fishing duration is 2.5-3 hours, i.e. a total of 5-6 hours per fishing day. Mudskipper juveniles are collected from the net every 30 minutes and stored in a bucket.

The juvenile bag-net is set at 64 m intervals in Bac Lieu province and 240 m intervals in Soc Trang province. The mouth of the bag-net is set opposite to the water current from the sea. The juveniles are carried by tidal current from the sea to the interior of the river. The caught juveniles are carefully selected and collected by scoop net. The juvenile size was approximately 1.8–2 cm total length. The catch yield was highest from June to September (Fig. 3) and none from December to April. The mean catch yield was calculated at 33,411±10,638 ind $net^{-1}$ $month^{-1}$; and the catch per unit effort (CPUE) was 200,466±85,565 ind $net^{-1}$ for the 6 month-period. The cost of juvenile bag-net was recorded at US$ 30±10.6 $net^{-1}$ in

Soc Trang and US$ 30.8±10 net$^{-1}$ in Bac Lieu province. The selling price of juvenile was US$ 0.0014 ind$^{-1}$. The benefit from juvenile fishing activity was US$319±220 per 6 months in Soc Trang and US$233±194 per 6 months in the Bac Lieu province.

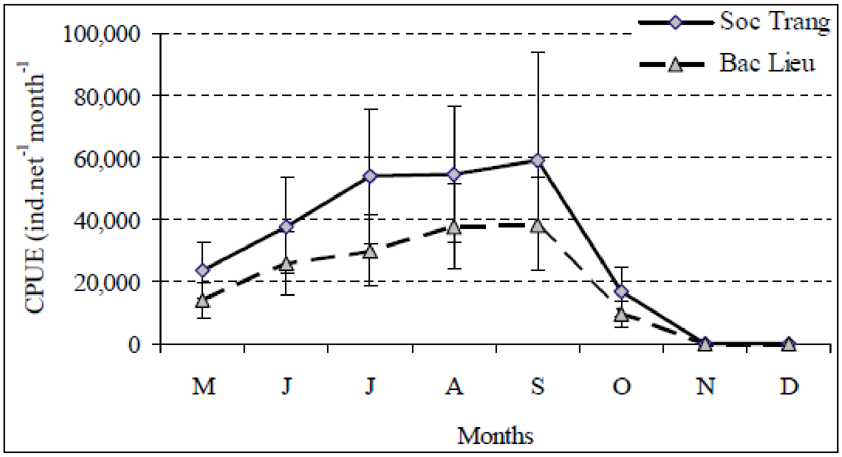


**Fig. 3.** Monthly catch per unit effort (CPUE) on mudskipper juveniles from May to December 2006 in Soc Trang and Bac Lieu provinces, Vietnam.

### *Mudskipper aquaculture*

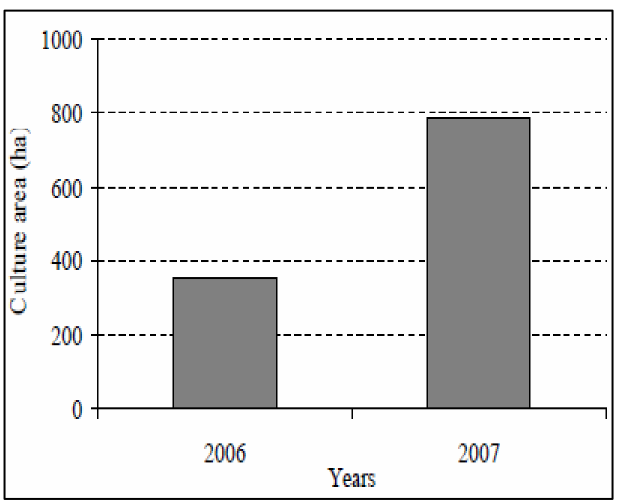


**Fig. 4.** Size of mudskipper culture area in Soc Trang and Bac Lieu provinces in Vietnam in 2006 and 2007.

Mudskipper culture has developed since 2001–2002 in the Mekong Delta. The *P. elongatus* culture area increased rapidly from 352 ha in 2006 to 787 ha in 2007 in the study area (DOFI 2007 & 2008) (Fig. 4). The study found that two major groups of mudskipper culture systems have developed in the Mekong Delta, the semi-intensive and intensive culture systems. The stocking density was grouped into two, the low density (semi-intensive) and high density (intensive) (Fig. 5a and 5b). Percentage of intensive farms was higher (53%) than semi-intensive farms (47%) in the study areas.

Before 2002, the livelihood of intensive and semi-intensive mudskipper farmers depended mostly on shrimp culture in both dry and rainy seasons. However, mudskipper culture replaced the intensive and semi-intensive shrimp culture during the rainy season in 2006 (Fig. 6 and 7). In these culture systems, two sub-groups of mudskipper farms were identified namely (1) monoculture of mudskipper and (2) rotation shrimp (in dry season) and mudskipper culture (in rainy season). However, this study focused only on mudskipper culture during rainy season. Some reasons for mudskipper culture development are shown in table 1.

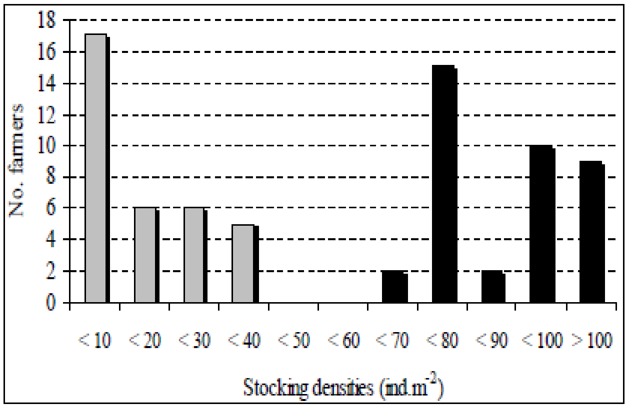


**Fig. 5a.** Stocking densities used by mudskipper farmers in Mekong Delta, Vietnam.

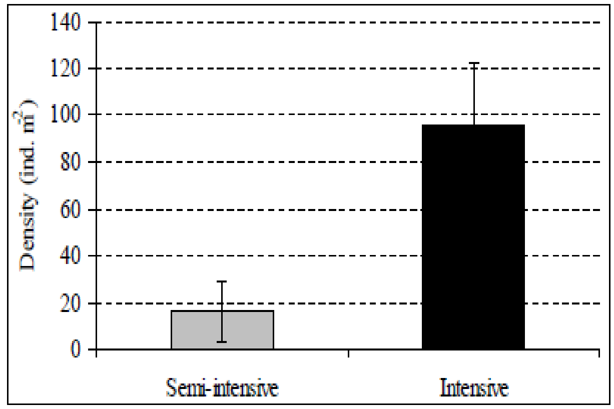


**Fig. 5b.** Stocking densities of semi-intensive and intensive systems

| Items | Mudskipper | Shrimp |
|---|---|---|
| Farming | Easy | Difficult |
| Environmental tolerance | High | Poor |
| Disease | Little | Serious |
| Production cost | Low | High |
| Market price | High | High |
| Profit | High | Low |
| Risk | Low | High |

**Table 1.** Reasons for shifting from shrimp farming to *P. elongates* farming. Responses were taken from interviews with mudskipper farmers who were previously shrimp farmers.

This study found technical differences between the intensive and semi-intensive mudskipper culture systems (Table 2). The stocking density in intensive culture system was higher (95.7±26.5 ind $m^{-2}$) than that of semi-intensive culture system (16.2±12.7 ind $m^{-2}$), without aeration applied for both systems. The juveniles were stocked in June or August in both systems. Ranges of salinity at stocking were 14-18 ppt in May and June and 5-8 ppt in August and September. In both culture systems, the juveniles were stocked at low water levels (25–35 cm) during the first 20 days. Water was filled up to 50 cm one month after stocking the juveniles.

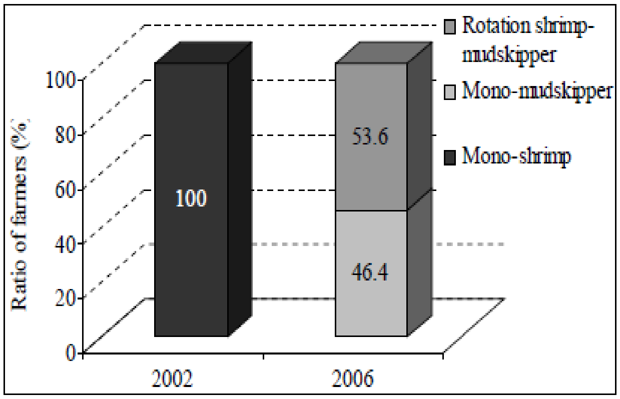


**Fig. 6.** Livelihood of intensive farmers in Mekong Delta, Vietnam in 2002 and 2006.

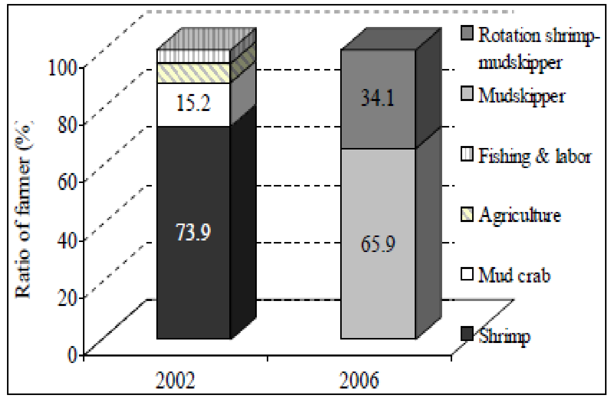


**Fig. 7.** Livelihood of semi-intensive farmers Mekong Delta, Vietnam in 2002 and 2006.

Water exchange was done by discharging 10-15 cm and filling up to 30 cm level one and a half months after stocking the juveniles. Water exchange and filling up were done two times each month by tidal regime and initial pumping in intensive farms, but only by tidal regime in semi-intensive farms. Benthos and plankton samples were not collected and analyzed in this study. Commercial pellets were used frequently (2 times per day) in intensive system, but only sometimes in semi-intensive system. Local commercial pellet feed (Dollars brand) was used by 75% of farmers. The protein content of the pellet feed is 35% as indicated in the feed bag. Average feed conversion rates (FCR) were recorded at 1.7 for intensive culture system and 1.4 for semi-intensive. The fish was harvested initially in intensive farms by pumping out water, while it was dependent on tidal regime in semi-intensive system. The harvest sizes ranged from 22-25 g $ind^{-1}$ for intensive farms and 21-22 g $ind^{-1}$ for semi-intensive farms. Survival rate of intensive farms was higher than that of semi-intensive farms. The yield of *P. elongatus* farming was quite higher in intensive culture system (8–10 times) than that of semi-intensive culture system (Table 2). The farm gate price of *P. elongatus* in intensive farms was higher than that of semi-intensive farms. Production costs of intensive culture system was much higher than that of semi-intensive system, in which feed and juvenile costs were the major expenses in the intensive (57.8±3.3% and 32.2±2.8%) and semi-intensive culture systems (51.6±5.9% and 28.3±2.6%) (Table 3). The net profit of intensive culture was 10 times higher than that of semi-intensive culture (Table 4). There were significant differences in cost, farm gate price and net profit between intensive and semi-intensive culture systems ($P < 0.05$). Ratio of benefit and cost in intensive farming was higher than in semi-intensive farming.

**Table 2.** Selected technical parameters of intensive and semi-intensive culture of *P. elongates* (values are mean ± s.d.).

| Items | Intensive (n=38) | Semi-intensive (n=34) |
|---|---|---|
| Pond size (ha) | 0.4-0.6 | 0.7–1 |
| Stocking density (ind. $m^{-2}$) | 95.7 ± 26.5 | 16.2 ± 12.7 |
| Juvenile size (cm) | 1.8-2.1 | 2.2-2.5 |
| Juvenile price (US$ $ind^{-1}$) | 0.0021-0.003 | 0.0035–0.0036 |
| Stocking months | May and Jun; Aug and Sep | May and Jun; Aug and Sept. |
| Salinity at stocking (ppt) | 14–18 and 5-8 | 14–18 and 5-8 |
| Initial water depth (cm) | 25–35 | 30–35 |
| Water depth (m) | 1 | 0.8–1 |
| Water exchange | Tidal and pumping | Tidal |
| Pond preparation | Rotenol, lime and fertilizers | Rotenol or lime or fertilizers |
| Frequency of feeding (times per day) | 2 | Sometimes only |
| FCR | 1.7 ± 0.4 | 1.4 ± 0.9 |
| Harvest | Initially by pumping | Tidal regime |
| Harvest size (g $ind^{-1}$) | 22–25 | 21–22 |
| Survival (%) | 31.4 ± 4.7 | 21.3 ± 5.6 |
| Yield (ton $ha^{-1}$) | 6.4 ± 1 | 0.77 ± 0.3 |

**Table 3.** Selected technical parameters of intensive and semi-intensive culture of *P. elongates* (values are mean ± s.d.).

| **Costs items** | **Intensive** (n=38) (%) | **Semi-intensive** (n=34) (%) |
|---|---|---|
| Juveniles | 32.1 ± 2.8 (a) | 51.6 ± 5.9 (b) |
| Feed | 57.8 ± 3.3 (a) | 28.3 ± 2.6 (b) |
| Hired labour | 6.9 ± 1.3 | 10.8 ± 1.1 |
| Pond preparation and diesel | 3.2 ± 0.9 | 7.5 ± 1.9 |
| Bank interest | | 1.8 ± 0.8 |
| **Benefit item** | | |
| Ratio of benefit per cost (B/C) | 160 ± 90 | 140 ± 120 |

**Table 4.** Cost-benefit analysis of two culture systems of *P. elongatus* (values are mean ± s.d.). Values in a row with different superscript are significantly different at P < 0.05.

| **Items** | **Intensive** (n=38) | **Semi-intensive** (n=34) |
|---|---|---|
| Total cost of farm (US$ $ha^{-1}crop^{-1}$) | 8,696 ± 1,191 (a) | 967 ± 308 (b) |
| Farm gate price of mudskipper (US$ $kg^{-1}$) | 3.4 ± 0.13 (a) | 2.6 ± 0.16 (b) |
| Net profit (US$ $ha^{-1}crop^{-1}$) | 12,784 ± 2,109 (a) | 1,039 ± 407 (b) |
| Ratio of benefit and cost (B/C) | 1.6 ± 0.9 | 1.4 ± 1.2 |

(US$ 1 = 16,500 VND)

## Discussion

### *Juvenile catch*

The juvenile fishing activity is considered as a spontaneous activity in recent years in the coastal areas of Mekong Delta. Juvenile fishing started earlier (2001) in the Bac Lieu province that supplied juvenile mudskipper (*P. elongatus*) for aquaculture in this province. Mudskipper culture systems were developed earlier in Bac Lieu than in other coastal provinces in the Mekong Delta, Viet Nam. In Taiwan and China, farming of mudskipper *B. pectinirostris* started in the 1960's and 1980's, respectively. The wild juveniles were collected from the open sea, leading to the decline of this species resource in China (Hong et al. 2007). The collection of wild juveniles of *P. elongatus* in the Mekong Delta might face a similar problem. Therefore, the resource of *P. elongatus* in the study areas needs to be managed to prevent its decline or depletion in the future. Meanwhile aquaculture development of *P. elongatus* has developed rapidly, while the artificial breeding of this species has not succeeded yet; this could bring additional pressure on the decline of wild resource.

Juvenile fishing activity is conducted during rainy season (from May to November), with the highest yield from June to September. The *P. elongatus* juveniles are caught during high tide and when water current moves from the sea into the interior of the river. This indicates that the spawning season of *P. elongatus* may occur in rainy season and the spawning ground in offshore areas. In another study, it was found that *P. elongatus* juvenile density was highest from June to September and lowest from December to April. In addition, the smallest size of *P. elongatus* juvenile (1.6 cm) was found toward offshore and larger size (1.8 cm) in interior river (Minh, unpubl. data). According to King (1995), most tropical species spawn in rainy season whenever endogenous factors become active and exogenous events in the surrounding environment such as light, salinity, food available, moon phase, and most commonly temperature changes. A recent study reported that reproductive season of another mudskipper species *Periophthalmus magnuspinnatus* is from May to July on the coastal mudflats in Southern Korea (Baeck et al. 2007). Shiota et el. (2003) reported that high temperature (30 $^{o}$C) induced gonadal development of mudskipper *P. modertus*, but not at low temperature (18 $^{o}$C).

The mean CPUE of *P. elongatus* juveniles was calculated at 200,466±85,565 ind net$^{-1}$ for 6 months; based on the current estimation of local fishermen that there are around 400 juvenile fishermen in the study area, each fisherman having 1–2 bag nets. This shows that at least 800,000 of *P. elongatus* juveniles were caught in the study areas. This fishing activity has been considered as an illegal activity in the study areas. Although provincial fishery managers have tried to prevent by several measures, the efforts have not been effective because of increasing demand for *P. elongatus* juveniles for aquaculture. The decline of the wild supply of *P. elongatus* juveniles can be prevented if seed production technology is developed in the Mekong Delta.

***Mudskipper culture***

Mudskipper culture has developed rapidly and intensively in the study areas. The culture area of *P. elongatus* has increased from 352 ha in 2006 to 787 ha in 2007 in studied sites (Soc Trang and Bac Lieu DOFI 2007 and 2008). The intensive culture system has developed since 2004 and the number of intensive farms has increased in 2005 and 2006. The development of mudskipper farms seems to be quite fast in the coastal areas of the Mekong Delta. However, it has raised a big concern for the lack of juvenile supply. Based on the stocking density and CPUE of mudskipper juvenile, the demand for this species can be estimated around 400-500 million ind $yr^{-1}$ to meet the demand of 1,000 ha that will be developed in the whole Mekong Delta in the near future. This will be a significant issue in fisheries management of this species. In China, a total of 13,000 ha were used for *B. pectinirostris* mono-culture and poly-culture with shrimps in earthen ponds. Although artificial mudskipper breeding succeeded and supplied around 2-5 million mudskipper juveniles annually for farming, it has not met the need yet (Hong et al. 2007). Therefore, *P. elongatus* seed production technology should be developed in the Mekong Delta to provide for a huge juvenile demand for aquaculture.

Recent livelihood of intensive and semi-intensive culture farmers has depended not only on shrimp but also on mudskipper or only on mudskipper farming. Shrimp farming in rainy season has shifted to intensive or semi-intensive mudskipper culture in the study areas. Almost half and more than half of monoculture farms were using intensive and semi-intensive systems, respectively. In semi-intensive mudskipper culture, there were some other minor culture types such as integrated mudskipper-shrimp-mud crab culture, rotation mudskipper with mud crab culture, and rotation mudskipper with *Artemia*. The main reasons for engaging in mudskipper culture are lower risk, lower investment and higher benefits compared to shrimp culture. This indicates that mudskipper is considered as a new potential species for coastal aquaculture development with diversified farming. At present, the number of intensive farms of mudskipper is increasing in the coastal area of the Mekong Delta, and there will be much higher demand for juvenile mudskippers in the future.

The current stocking density of mudskipper (*P. elongatus*) in the Mekong Delta was much higher than in the mudskipper (*B. pectinirostris*) stocked in China, i.e. 4.5-7.5 ind $ha^{-1}$ (Hong et al. 2007). In our study, although mudskippers were stocked quite high density in ponds, i.e. 95.7±26.5 ind $m^{-2}$ in intensive farms and 16.2±12.7 ind $m^{-2}$ in semi-intensive farms, aeration was not supplied in all mudskipper farms. This shows that mudskipper can adapt extremely to low oxygen condition. According to Aguilar et al. (2000), mudskippers are amphibious fishes that hold air in their large bucco-pharyngeal-opercular cavities where respiratory gas exchange takes place via the gills and a highly vascularized epithelium lining the cavities. They use the bucco-pharyngeal-opercular cavity as respiratory organ. They also reported that although most amphibious and other air-breathing fishes may be forced to respire in hypoxic or hypercapnic water, they do not normally encounter aerial hypoxia or hypercapnia. According to Ishimatsu et al. (1998), mudskippers may respire naturally hypoxic and hypercapnic air. When confined to normoxic water, mudskipper irrigated intermittently the gills with water, but increased aquatic ventilation frequency in aquatic hypoxia and decreased it in hyperoxia (Martin and Bridges 1999). In addition, many air-breathing fishes increase air-breathing frequency in response to aquatic hypercapnia (Graham 1997). The physiological threshold of other mudskipper (*Scartelaos gigas*) was reported in the ranges of 0.86-1.43 mg $L^{1-}$ (Lee et al. 2006). Therefore, aeration has not been needed in mudskipper farming and there is a potential to further increase the stocking density. However, suitable stocking density for *P. elongatus* culture has not been known yet.

Juvenile mudskippers were stocked in rainy season due to the availability of wild juveniles. The ranges of salinities were 14–18 ppt in May and June and 5–8 ppt in August and September 2006. This salinity range could be suitable for *P. elongatus* culture. According to Chen et al. (2008), behavioral preferences of the early juvenile mudskipper (*B. pectinirostris*) for temperature, salinity and sediment were found at 31±5 $^{o}$C of temperature (27-34 $^{o}$C), and 5 ppt of salinity, but sediment could be critical factor for determining the distribution of the mudskipper. Furthermore, Takita et al. (1999) reported that *P. elongatus* has wide salinity tolerance. Being a euryhaline species, *P. elongatus* can survive a wide range of salinity from 0 to 50 ppt. (Bucholtz et al. 2008).

The juveniles were stocked at low water level (25–35 cm) during the first 20 days. Then water was added up to 50 cm and then 80-100 cm in the next months of culture. This is done in consideration of the biological characteristics of mudskippers. According to Takita et al. (1999), young *P. elongatus* (less than 7 cm standard length) are common in water pools on mudflats in river mouths and seashores. This indicates that *P. elongatus* is an extremely tolerant species and easier to culture than shrimp (*Penaeus monodon*), thus, almost half of the shrimp farms were converted to *P. elongatus* farms in rainy season (May to November) in the Mekong Delta.

Water exchange in intensive farms was done by pumping and by tidal regime in semi-intensive farms. This can be explained by the fact that most intensive farms were previously intensive shrimp ponds and then used for mudskipper intensive farming in rainy season. Thus, farm facilities such as water pumps and water supply and drainage sluice gates in intensive farms were better than in semi-intensive farms. At present, the nutrient requirement of *P. elongatus* is not known yet. According to Yang et al. (2003), the mudskipper (*B. pectinirostris*) is herbivorous and mainly feeds on diatom on mudflats and this is confirmed by our recent study showing that *P. elongatus* has a relative gut length (RGL) of 1.4±0.4 and the gut content is mainly (85-86%) composed of Chlorophyta (*Nannochloropsis*) in rainy and dry seasons (Minh, unpubl. data). Recent study reported that *P. elongatus* is herbivorous and mainly feeding on pennate diatoms, i.e. 93% of the diet in dry season (Bucholtz et al. 2008). At present, specific commercial feeds for this species has not been formulated yet. This could be a constraint for the development of high intensive mudskipper culture in the Mekong Delta.

Although the survival rates were not high in both systems, yields were higher in intensive system (6.4±1 ton $ha^{-1}$) than in semi-intensive system (0.77±0.3 ton $ha^{-1}$). The yield in this study was higher than the yield of mudskipper (*B. pectinirostris*) farms in China, i.e. 0.75 ton $ha^{-1}$ to 0.98 ton $ha^{-1}$ (Hong et al. 2007). This indicates that the mudskipper farming in the Mekong Delta has a great potential of yield and can be developed in the future, but careful management must be undertaken to avoid negative effects on the environment. There is also a need to improve survival rates in both culture systems.

Farm gate price of mudskipper in intensive farms was significantly higher (US$ 3.4±0.13 $kg^{-1}$) than that of semi-intensive farms (US$ 2.6±0.16 $kg^{-1}$) because intensive culture farmers could adjust the harvest time without depending on the tidal regime. They can harvest initially whenever there is a high demand for mudskipper in the market, i.e. scarce supply of natural mudskippers during neap tide period. Meanwhile, harvesting in semi-intensive, farmers depends on tidal regime at high tide period during which wild mudskippers are also caught by river bag-net fishermen. This leads to a decrease in market price. Timing of harvest is one important factor contributing to high profit in intensive culture system.

## Conclusions and Recommendations

The high economic value and market demand for mudskipper lead to increasing high catch pressure of wild *P. elongatus* juvenile for aquaculture, and threatens the decline of this species resource in the Mekong Delta in the future. In order to manage and prevent the decline of this species, seed production technology needs to be developed to provide a steady source of *P. elongatus* juvenile for aquaculture. In addition, there is a need to limit the number of juvenile bag-nets, catching time, and apply community-based management for the resource in given areas.

Mudskipper (*P. elongatus*) is a potential species for coastal aquaculture and easy to farm in intensive or semi-intensive systems during rainy season in the Mekong Delta. This species is considered as an alternative species to shrimp farming in rainy season. Mudskipper can be farmed in diversified culture systems such as mono-culture, rotation with shrimp, or integrated with shrimp and mud crab culture. However, the techniques on mudskipper culture still need to be developed through research. Therefore, this study proposes that research on *P. elongatus* culture techniques should be conducted to improve the survival rate and yield of intensive and semi-intensive culture systems in the Mekong Delta, and to prevent possible negative effects of the culture system on the environment.

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