Development of Crab Farming: The Complete Cycle of Blue Swimming Crab Culture Program (CBSC Program) in Thailand

Vutthichai Oniam* and Wasana Arkronrat

ABSTRACT

The blue swimming crab, *Portunus pelagicus*, is a commercially important species of the tropical Indo-Pacific region which shows substantial potential as a candidate species for aquaculture. The complete cycle of blue swimming crab culture program (CBSC program) was an integrated research for development of *P. pelagicus* culture by Klongwan Fisheries Research Station, Faculty of Fisheries, Kasetsart University, Thailand, which began in 2008. The knowledge of CBSC program events can be used as a basis for the development of the crab aquaculture system, e.g. crab broodstock and seed production. A review of literature indicates that the hatching rate and larval quality from *P. pelagicus* broodstock reared in earthen ponds are comparable to those from the sea. Female crabs held in ponds for at least 120 days could be used as broodstock, a mixed feed of 50% trash fish and 50% shrimp feed No. 4 was suitable for rearing crab broodstock, and the second brood of female *P. pelagicus* can be used for seed production. In summary, the CBSC program is an alternative option for *P. pelagicus* production and the development of crab farming in Thailand. The approach for development of improved crab broodstock, seed production and grow-out under CBSC program, and reducing mortality in crab are interesting points for future research.

Key words: blue swimming crab, *Portunus pelagicus*, CBSC program, crab production

INTRODUCTION

The blue swimming crab, *Portunus pelagicus* (Linnaeus 1758), a commercially important species, is distributed throughout the coastal waters of the tropical regions of the western Indian and the eastern Pacific Oceans (Xiao and Kumar, 2004). Exportation of pasteurized *P. pelagicus* meat to the United States of America, Japan, and Singapore generates multi-million dollar annual revenues for Indonesia. The Indonesian crabs come from the wild, not from aquaculture. To meet the increasing market demand for soft-shell crabs (*P. pelagicus*), crabs have been individually held in compartments within a re-circulating system to produce soft-shell crabs in Australia (Romano and

Klongwan Fisheries Research Station, Academic Support Division, Faculty of Fisheries, Kasetsart University, Prachuap Khiri Khan 77000, Thailand.

* Corresponding author, E-mail: toey.oniam@gmail.com

Zeng, 2006). In Thailand, *P. pelagicus* for direct consumption and for use as a raw material in the processing industry are caught in the Andaman Sea and the Gulf of Thailand. Annual exportation of fresh, chilled, or frozen crabs to the USA, Japan, Taiwan, and other countries, is a multi-million dollar revenue business for Thailand. However, the production of crabs from capture fisheries has shown a decreasing trend due to overfishing and/or changes in the coastal and marine environments. For example, the production of *P. pelagicus* in the sea of Thailand dropped from 29,500 t in 2004 to 22,800 t in 2010 (Department of Fisheries, Thailand 2012). Therefore, *P. pelagicus* aquaculture is believed to be one way of increasing the productivity without placing undue pressure on the wild stock and on the food security for the local communities.

Currently, many countries are actively involved in *P. pelagicus* culture and associated research, e.g. Australia, India, Indonesia, Malaysia and the Philippines (Josileen and Menon, 2005; Romano and Zeng, 2008). In Thailand, *P. pelagicus* culture methods of breeding (Tanasomwang *et al*., 2002; Kaoeian and Chindamaikul, 2004; Oniam *et al*., 2009), nursing (Chutpoom and Tanasomwang, 2005; Tanasomwang *et al*., 2006; 2007) and rearing (Kedmuean *et al*., 2004; Thepphanich and Chumworathayi, 2005; Thepphanich *et al*., 2008) have been developed to gain higher productivity and survival rates. The method of rearing crab broodstock in earthen ponds is also well developed (Oniam *et al*. 2009; 2010; 2012c), including the complete cycle of blue swimming crab culture program (CBSC program).

The CBSC program was an integrated research for development of *P. pelagicus* culture. This program, initiated in 2008, was established and developed by Klongwan Fisheries Research Station (KFRS), Faculty of Fisheries, Kasetsart University (KU), Thailand for crab broodstock and seed production (Oniam *et al*., 2012a). However, in most of the countries to date, hatchery seed production of *P. pelagicus* has been experimental. Rearing technologies for crab production have not been established on a commercial scale and rearing alone still could not sustain a farmer's income because of low productivity. Thus, the objectives of this review were to summarize the CBSC program and the cause of mortality in crabs. The knowledge gained from this review will be useful for crab production and the development of crab farming, which are both important for future job stability of farmers.

The CBSC program

The CBSC program was implemented at the hatchery and earthen ponds of KFRS, Prachuap Khiri Khan Province, Thailand. The production process of the CBSC program is presented in Fig. 1.

Source of female crabs (G1) in pond-reared broodstock under CBSC program

The *P. pelagicus* broodstock were caught using crab traps used by small-scale fishermen in the coastal area of Prachuap Khiri Khan Bay, Prachuap Khiri Khan Province, Thailand. The female crabs (G0) with dark grey eggs were placed in 200 L fiber tanks to allow them to release the eggs for hatching. They were not fed during this

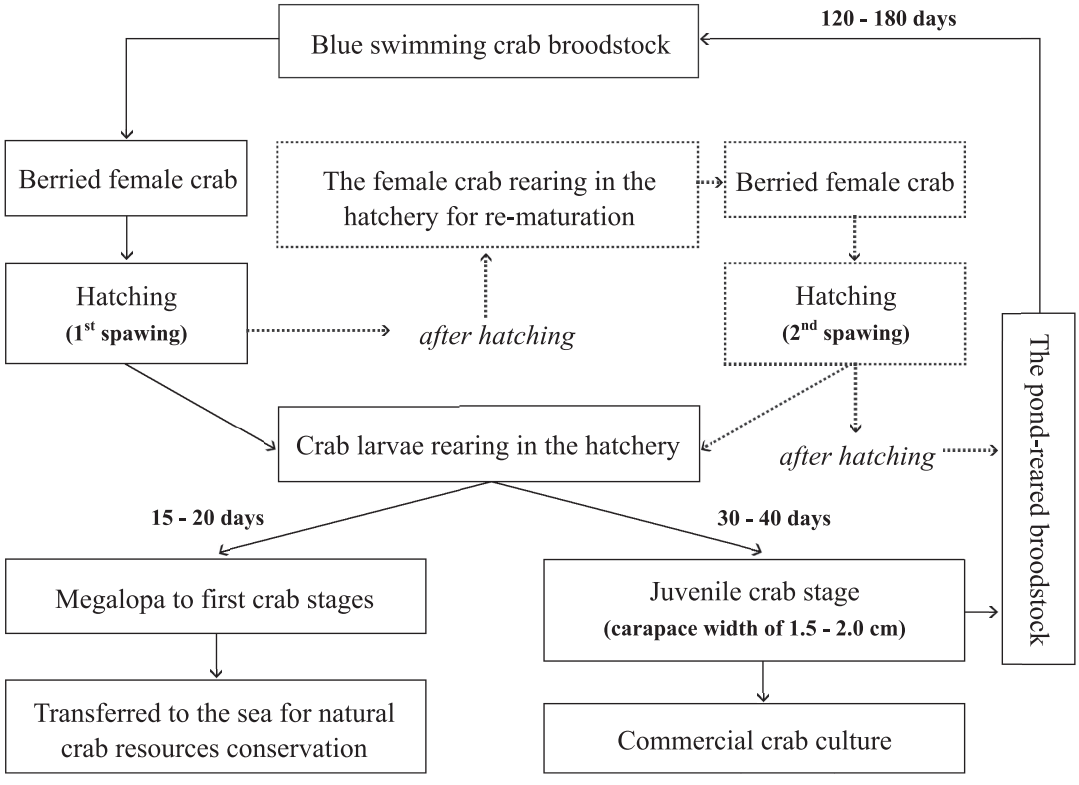


Figure 1. The production process of the CBSC program
Source: Oniam *et al.* (2012a)

period. The newly hatched crab larvae were transferred to 3,000 L concrete tanks for nursing at a density of 100 crabs/L. Crabs with carapace width of 1.5-2 cm (about 45 days after hatching) from the nursing concrete tanks were transferred to 400 m^2 earthen ponds (20 m length x 20 m width x 1 m depth) at a density of 3 crabs/m^2. Crab broodstock were fed with mixed feeds (50% trash fish and 50% shrimp feed No. 4) at 5% of body weight per day, twice a day at 9.00 a.m. and 4.00 p.m. (Oniam *et al*., 2012c) until they reached crab broodstock size (G1) or about 120-180 days (Oniam *et al*., 2010). In crab broodstock rearing, about 30% of the total water volume was exchanged once a week.

Source of crab larvae production in hatchery under CBSC program

The berried female crabs with dark grey eggs from pond-reared broodstock (G1) were transferred into 200 L plastic tanks for hatching. After hatching, the crab larvae were transferred outdoors to 3,000 L concrete tanks for nursing at a density of 100 crabs/L. The crab larvae from the zoea I to first crab stages were fed with diatom (*Chaetoceros* sp. or *Thalassiosira* sp.), rotifer (*Branchionus* sp.) and *Artemia* nauplii according to Arkronrat and Oniam (2012) (Table 1). In larval nursing, about 30% of the total water volume was exchanged every 3 days during the

Table 1. Feeding schedule (per day) for blue swimming crab (*P. pelagicus*) larvae.

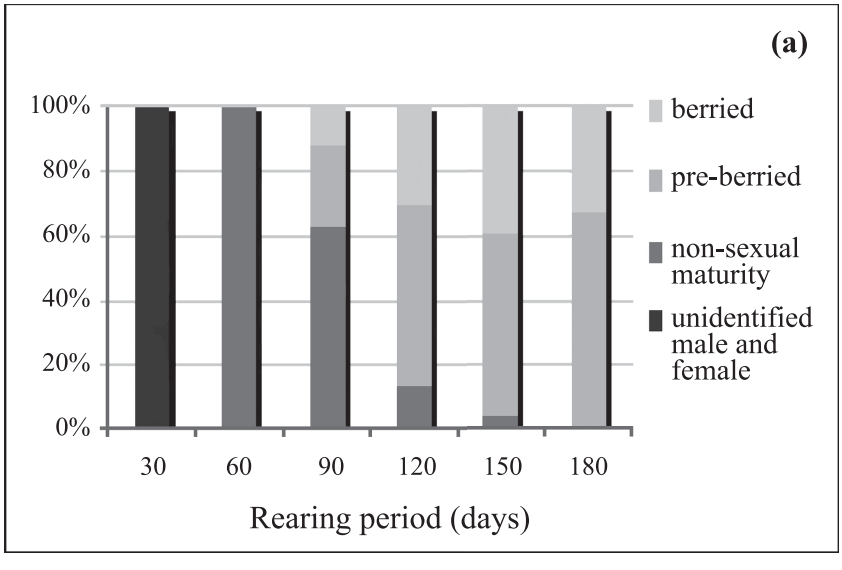
Crab larval stage at densities of 100 crabs/L				
Zoea I	Zoea II	Zoea III-IV	Zoea IV-Magalopa	Magalopa -1st crab
Thalassiosira spp. ($1\text{-}2\times10^4$ cells/ml)	*Thalassiosira* spp. ($1\text{-}2\times10^4$ cells/ml) + Rotifer (density of 10/ml)	*Thalassiosira* spp. ($1\text{-}2\times10^4$ cells/ml) + Rotifer (density of 10/ml) + *Artemia* nauplii (density of 5/ml)	Rotifer (density of 10/ml) + *Artemia* nauplii (density of 5/ml)	*Artemia* nauplii (density of 5/ml)

Source: Adapted from Arkronrat and Oniam (2012)

zoea I to megalopa stages, while during the megalopa to first crab stages there was about 30% daily water exchange. The crab larvae rearing in the hatchery until to size appropriate for natural crab resources conservation, commercial crab culture and re-broodstock culture (G2-G3).

Output of CBSC program

The CBSC program implementation reported by Oniam *et al*. (2010) disclosed that berried female crabs were first found on day 90 (12.73% all female crab) with the prominent peak on day 150 (38.99% all female crab) of the rearing period. At day 150, the percentage of yellow, brown and dark grey coloured eggs were 41.11, 34.44 and 24.45%, respectively. The percentage of non-sexual mature female, internally egg-bearing (pre-berried) and externally egg-bearing (berried) were shown in Figure 2.



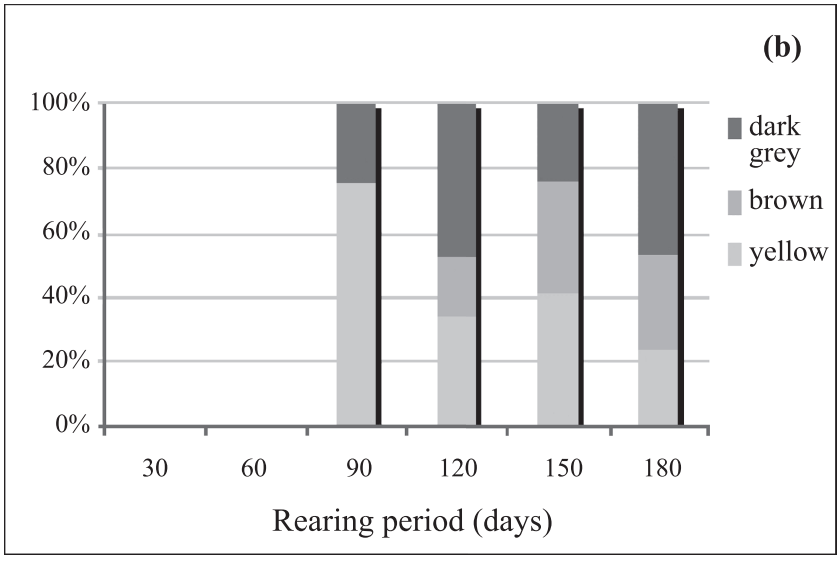


Figure 2. Percentage composition of female blue swimming crab (*P. pelagicus*) reared in the earthen ponds: female sexual maturity (a) and berried female (b).
Source: Oniam *et al.* (2010)

The female *P. pelagicus* were reared in a broodstock pond for 120-180 days under the following conditions: salinity 29-34 ppt, temperature 28.7-32.8^{o}C, dissolved oxygen 3.90-8.11 mg/L, pH 7.86-9.22. The broodstock had a mean carapace width of 10.86±1.50 cm, carapace length of 5.17± 0.83 cm, body weight of 103.11±44.75 g, fecundity of 530,180±237,767 eggs and hatching rate of 50.06±28.41 % (Table 2). The mean products of zoea I and first crab stages from the CBSC program were nursed under the following conditions: salinity 30-32 ppt, temperature 28.0-31.1^{o}C, dissolved oxygen 4.21-5.67 mg/L, pH 8.01-8.69, total ammonia 0.000-0.274 mg-N/L, nitrite 0.000 -0.483 mg-N/L and alkalinity 105-139 mg/L as $CaCO_3$ were 378,859±195,723 and 2,684 ±2,445 crabs per female crab, respectively (Table 2).

In addition, growth rate trials of the *P. pelagicus* reared in the earthen ponds were conducted for 90 and 150 days under the following rearing conditions: salinity 31-35 ppt, temperature 30.0-34.3^{o}C, dissolved oxygen 4.03-8.96 mg/L, pH 8.18-9.29, total ammonia 0.000-0.036 mg-N/L, nitrite 0.000-0.020 mg-N/L, alkalinity 105-136 mg/L as $CaCO_3$ and transparency 35-70 cm as shown in Table 2.

In the CBSC program, the *P. pelagicus* broodstock from the earthen ponds had hatching rates and larval quality which were comparable with those collected from the sea (Oniam *et al*., 2009; Oniam and Taparhudee, 2010). The female crabs grown in pond for at least 120 days could already be used as broodstock. The zoea I produced by female crabs in ponds for only 90 days had

Table 2. The blue swimming crab (*P. pelagicus*) production under the CBSC program.

Parameter observed	Results		Reference
	Min.-Max.	Mean±SD.	
Crab broodstock			Oniam *et al*. (2012a)
- optimum culture period (days)	120-180	-	
- carapace width (cm)	7.7-15.2	10.86±1.50	
- carapace length (cm)	3.7-8.8	5.17±0.83	
- body weight (g)	35-245	103.11±44.75	
- first spawning			
fecundity (eggs)/female	110,150-1,431,950	530,180±237,767	
hatching rate (%)	0.00-99.86	50.06±28.41	
Crab larvae (crabs/female crab)			
- newly hatched larvae (Z1)	30,000-1,259,940	378,859±195,723	
- first crab stage (C1)	0-11,076	2,684±2,445	
Crab broodstock			Oniam and Arkronrat (2012)
- second spawning			
fecundity (eggs)/female	88,120-660,900	337,435±163,411	
hatching rate (%)	0.00-86.24	37.71±20.95	
Crab in grow-out			Oniam *et al*. (2010)
- 90 days of culture			
carapace width (cm)	-	8.66±0.73	
carapace length (cm)	-	4.29±0.41	
body weight (g)	-	50.59±12.53	
- 150 days of culture			
carapace width (cm)	-	11.09±1.35	
carapace length (cm)	-	5.29±0.74	
body weight (g)	-	111.68±42.33	

a significantly lower survival rate compared to those produced by female crabs in ponds for 120, 150 and 180 days (Oniam *et al*., 2010), and zoea I produced by crab broodstock fed with mixed feeds (50% trash fish and 50% shrimp feed No. 4) had a higher survival rate compared to those produced by crab broodstock fed with trash fish and shrimp feed (Oniam *et al*., 2012c). In addition, the second brood of female *P. pelagicus* can be used for seed production. Oniam and Arkronrat (2012) reported that after *P. pelagicus* hatching (first spawning), the female crabs were reared individually in plastic baskets in 2,000 L concrete ponds, at 8 baskets per pond. On the bottom of the plastic baskets, sand substrate (around 10 cm thick) was provided for the female crabs to bury in and to facilitate the attachment of eggs to their abdomens during the ovarian re-maturation for second spawning.

The financial analysis of CBSC program found that revenue from seed

production would cover the cost but revenue from crab production of 15-20 crabs/kg in earthen ponds would not cover the cost. The investment in crab production of 8-10 crabs/kg had a relatively high risk due to the changes in cost and benefit for investments (Table 3). Oniam *et al*. (2012b) reported that crabs reared for 30 days had a higher feed intake (31.30±6.96% body weight/day) compared to those crab reared for 60, 90 and 120 days (4.76±1.97, 2.94±1.21 and 2.55±1.00% body weight/day, respectively), and feed intake of crabs reared for 90 and 120 days were not different.

Table 3. The average cost and benefit of blue swimming crab (*P. pelagicus*) production under CBSC program.

Items	Crab production		
	Crab larvae	15-20 crabs/kg	Crab broodstock and 8-10 crabs/kg
General information			
- culture area	tank (3 m^2)	earthen pond (400 m^2)	earthen pond (400 m^2)
- density of crab	100,000 crab/m^2	5 crab/m^2	3 crab/m^2
- rearing period	25 day	90 day	150 day
- average survival rate	0.89±0.80%	57.40±17.89%	34.92±7.36%
- average yield	2,841±3,010 crab/tank	57.97±18.07 kg/pond	46.76±9.86 kg/pond
Average cost per year			
- seed cost	600 Bath/tank	6,000 Bath/pond	2,400 Bath/pond
- feed cost	1,683 Bath/tank	8,419 Bath/pond	3,400 Bath/pond
- other cost	4,576 Bath/tank	2,243 Bath/pond	1,812 Bath/pond
Benefit per year			
- sale price	0.5 Bath/crab	70 Bath/kg	110 Bath/kg
- total revenue	17,046 Bath/tank	12,173 Bath/pond	10,287 Bath/pond
- net cash return	10,187 Bath/tank	-4,489 Bath/pond	2,675 Bath/pond

Source: Adapted from Oniam *et al*. (2011a).

The factors affecting crab production

Rearing technologies for the production of *P. pelagicus* have not been established on a commercial scale and rearing alone still could not sustain a farmer´s income because of low productivity. Many researchers reported that the factors that contribute to low survival of crab larvae were identified as feedstock (Soundarapandian *et al*., 2007; Castine *et al*., 2008), cannibalism (Moksnes *et al*., 1998; Marshall *et al*., 2005; Møller *et al*., 2008), water quality (Romano and Zeng, 2006; 2007; Liao *et al*., 2011), light intensity and photoperiod (Andrés *et al*., 2010), among others. Ikhwanuddin *et al*. (2012) reported that higher/lower stocking density affected survival, growth and development of *P. pelagicus* larvae. Densities higher than 200 larvae/L were not suitable

for culture conditions. In addition, Oniam *et al*., (2010) reported that zoea produced by female *P. pelagicus* broodstock younger than 120 days had a significantly lower survival rate compared to those produced by older female broodstock, and the causes of crab larvae mortality were moult death syndrome (MDS or death associated with moulting), bacterial disease, parasites and fungi (Morado, 2011; Wang, 2011). Marshall *et al*. (2005) and Maheswarudu *et al*. (2008) reported that the factors that contribute to low survival of megalopa to first crab stages were MDS and cannibalism. While MDS may have occurred in the ponds, cannibalism was the main factor affecting mortality.

Cannibalism is a serious problem in decapod crustaceans, (Abdussamad and Thampy, 1994; Lovrich and Sainte-Marie, 1997; Fernandez, 1999; Møller *et al*., 2008). The occurrence of cannibalism is usually associated with limited food availability, high population density and limited space (Soundarapandian *et al*., 2007). In crab larvae nursery, cannibalism commonly occurs at the megalopa instar stage of crab development when the larvae develop chelipeds. Cannibalism, especially at the megalopa and juvenile stages, is one of the main reasons for failures in the development of rearing methods for a variety of crab species (Arshad *et al*., 2006; Ventura *et al*., 2008). The availability of refuge has been considered as one of the important factors affecting cannibalism in crabs. Marshall *et al*. (2005) reported that cannibalism in *P. pelagicus* juvenile might partially be controlled by refuge availability and increased refuge density. These methods increased the survival of crab larvae proportionally. Similarly, cannibalism in other crabs is reduced with the presence of artificial refuge areas (Luppi *et al*., 2001; Ut *et al*., 2007). In grow-out, Oniam *et al*. (2011b) reported that the factor that contributed most to high mortalities in crab culture was cannibalism, especially during 30 to 45 days of culture period. This was because crabs were small during the first 45 days (<7.5 cm carapace width) and smaller crabs had a high moulting frequency, compared to larger crabs reared for 60 days and onwards. After the crab moults (crabs with soft-shells), it enters the postmoult stage, and continues to harden over the next 24 h after which it will enter the intermoult stage (Marshall *et al*., 2005). Cannibalism is recorded in the postmoult stage of the crab. This was due to the crab having thin integuments, which cannot provide serious protection during attacks against each other (Marshall *et al*., 2005). Marshall *et al*. (2005) also reported that body size and moulting of crabs were the factors correlated with the likelihood of cannibalism. Smaller crabs (<60 mm carapace width) were cannibalised early and the rate of cannibalism increased with all moult stages: intermoult, premoult and postmoult. Hence, the mortality rate of crabs due to cannibalism decreases as the crab's age increases. Meanwhile after 90 days of culture, other factors contributed more to the mortality of the crabs. Although cannibalism is the main factor causing high mortality of *P. pelagicus* in ponds, the shelter on the pond bottom plays an important role in reducing cannibalism (Oniam *et al*., 2011b).

Mortality from other factors in crab culture could have been caused by MDS (Maheswarudu *et al*., 2008), nutritional quality of feed (Chaiyawat *et al*., 2008;

Soundarapandian and Dominic Arul Raja, 2008; Oniam *et al*., 2012c) and pond bottom soil quality (Oniam, 2011). Oniam (2011) also reported that the factors that contribute to lower productivity of commercial crab culture were cannibalism and soil quality, especially after 90 days of culture. This is the period when the pond bottom soil quality causes mortality of the *P. pelagicus* more so than cannibalism, i.e. changing properties of ammonia concentration and soil pH in pond bottom soil affecting productivity and FCR of *P. pelagicus* reared. However, more extensive research is needed to investigate the factors causing mortality in crab, such as cannibalism, diseases and pond bottom soil quality, in order to increase survival.

CONCLUSION

The CBSC program is an alternative option for *P. pelagicus* production and the development of crab farming, which are both important for the future job stability of farmers. However, the approach for development of improved crab broodstock and juvenile crab production, and reducing mortality in crab are interesting points for future study. The key recommendations for *P. pelagicus* culture development are as follows:

1. Crab broodstock production: study of dietary protein level and quality, HUFA levels and amino acids on reproductive performance of *P. pelagicus* broodstock reared in earthen pond.

2. Seed production: improve methods to reduce cannibalism in nursery stages, e.g., study of shelter quality (number, size and type of the shelter), and improve rearing management to increase survival rate (e.g. improve/control water quality, develop alternatives to live feeds)

3. Grow-out production: reduce cannibalism through improved shelters, develop formulated diets (ingredient selection, nutritional requirements, pellet size and stability) and improve or control pond bottom soil quality.

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