Promoting Responsible Aquaculture for the Sustainable Production of Soft-shell Crabs

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Soft-shell crabs command a high price because these could be eaten whole when cooked. Myanmar, Viet Nam, and Thailand are among the Southeast Asian countries that produce considerable quantities of soft-shell crabs mostly sold to local restaurants as well as exported to Australia, Europe, Hong Kong, Japan, Singapore, South Korea, Taiwan, and the USA. Production of soft-shell crabs is an emerging technology in the Philippines, where the demand for this product has been increasing and the technology becoming a growing interest. With prices that could range from US$ 10 to US$ 15 US$ or higher per kilogram depending on the size, soft-shell crabs are bought in bulk by elite restaurants in the Philippines that usually serve this delicacy with complimentary food or drinks. Although the demand for soft-shell crabs is high, production is still unstable due to lack of seedstocks, which are mainly sourced from the wild. To reduce the pressure on the natural population, SEAFDEC/AQD has initiated the development of soft-shell crab technology using hatchery-produced seedstocks, and is currently promoting the use of hatchery-produced seedstocks for soft-shell crab farming to local and international stakeholders all over the Southeast Asian region through its training courses. With funding support from the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) of the Department of Science and Technology (DOST) through its National Mud Crab Science and Technology Program (NMCSTP), SEAFDEC/AQD has intensified the development of the soft-shell crab technology. Applicable to all mangrove (mud) crab species, the technology for the production of soft-shell crabs could now be pursued using hatchery-produced seedstocks is described in this article.

Soft-shell crab in this article refers to any mangrove or mud crab (*Scylla*) species that has undergone a process in its life cycle called molting. In some countries, crab species like the blue swimming crabs (*Portunus pelagicus*) (Azra and Ikhwanuddin, 2015) and blue crabs (*Callinectes sapidus*) (Oesterling, 1988) are used for soft-shell crab production. As part of development, crabs often molt during their life cycle in order to grow, metamorphose, and reproduce. Crabs shed their old exoskeleton to be replaced by a new membranous sheath of decalcified, hydrated, and brief soft shell. With this temporary period of having a very pliable and soft exoskeleton, the crabs are referred to as "soft-shell" or "softy" crabs (Tavares, Silva, Pereira, & Ostrensky, 2017; Hungria *et al*., 2017; Quinitio *et al*., 2015; Kuballa and Elizur, 2007).

Crabs undergo four stages of the molting cycle starting with the molt stage, when the crabs tend to shed off their exoskeleton by quick adsorption of water and air from the environment, then the old shell breaks. Although this stage is considered the weakest part of the crabs' growth cycle and is also the most stressful, the crabs increase 30-50 % in size after molting. The second stage is postmolt where crabs are inactive and start to uptake water to expand the new and soft exoskeleton, then, the exoskeleton mineralizes and starts to harden. The third stage is the intermolt, considered as the longest among other molt stages where crabs slowly develop their tissue. At the fourth stage, crabs separate the exoskeleton from the membranous sheath (**Figure 1**) and prepare for the onset of another cycle of ecdysis or molting. Movement and feeding are reduced as the crabs lose its muscle insertions during this stage (Kuballa and Elizur, 2007).

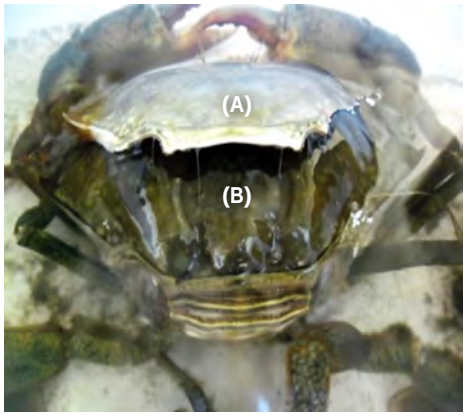

Figure 1. A molting mangrove crab (*Scylla serrata*): old and molted exoskeleton **(A)** pulling off; the membranous layer **(B)** could be observed

(Photo: ET Quinitio)

Mangrove Crab Species

The "mangrove crab" became the standard common English name for the *Scylla* species based on the Resolution adopted during the First National Mud Crab Congress in Iloilo, Philippines in 2015, which prescribed that the *Scylla* species should be called "mangrove crab" replacing the term "mud crab" as this connotes a negative impact to the marketability of the crabs. Also, the term "mangrove crab" links the four *Scylla* species to their natural habitat, the mangrove areas, and emphasizes the significance of mangrove forest conservation (Quinitio, Parado-Estepa, & Coloso, 2017).

Keenan *et al*. (1998) has identified the four distinct *Scylla* species of mangrove crabs as *Scylla serrata* (giant or king crab), *S. tranquebarica* (purple mangrove crab), *S. olivacea* (orange mangrove crab), and *S. paramamosain* (green mangrove crab). Primarily, the four species differ in the shapes and heights of their frontal spines; number and height of spines located on their chelipeds, and the pattern of markings on their legs and color of their shell (Quinitio and Estepa, 2008).

Table 1. Morphological features of *Scylla* species

Scientific name and common English name	Frontal spines		Chelipeds		Color and markings
	Shape	Height	Carpus spines	Propodus spines	
Scylla serrata giant or king mangrove crab	pointed	high	both obvious	obvious	Carapace green to almost black; polygonal pattern visible on chelipeds and legs of both sexes and the abdomen of the mature female
S. tranquebarica purple mangrove crab	blunt	moderate	both obvious	obvious	Carapace green to almost black; polygonal pattern obvious on last two pairs of legs but obscure on chelipeds and other legs of both sexes
S. olivacea orange mangrove crab	rounded	low	inner absent, outer reduced	Reduced	Carapace is brownish to brownish green in color; chelipeds and legs rusty brown and polygonal pattern absent
S. paramamosain green mangrove crab	triangular	moderate high	inner absent, outer reduced	obvious	Carapace green to light green; the obscure polygonal pattern on chelipeds and legs in both sexes

Source: Quinitio & Parado-Estepa (2008)

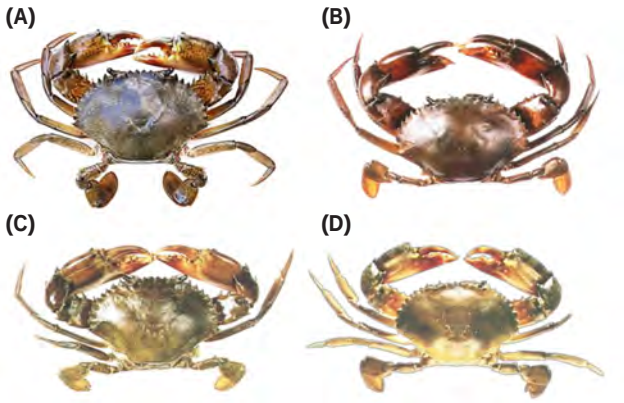

Figure 2. The four mangrove crab species: **A.** *Scylla serrata* or giant or king mangrove crab; **B.** *S. tranquebarica* or purple mangrove crab; **C.** *S. olivacea* or orange mangrove crab; and **D.** *Scylla paramamosain* or green mangrove crab

(Photos: Keenan et al., (1998))

The four *Scylla* species are illustrated in **Figure 2**, and the morphological features of each mangrove crab species are described in **Table 1**.

Farming of Soft-shell Crabs

In the Philippines, the production of mangrove crabs entails long- and short-term cultures, taking four to six months to produce marketable size in long-term grow-out culture. On the other hand, short-term culture engages in the fattening of lean crabs for 15-45 days (Williams and Primavera, 2001) and production of soft-shell crabs (Quinitio and Noe Lwin, 2009; Ganesh *et al*., 2015; Quinitio *et al*., 2015).

For soft-shell crabs, production could be done on a communal or an individual setup, starting with the outsourcing of 60-100 g body weight (BW) hard-shell crabs in intermolt and premolt stages (Quinitio and Noe Lwin, 2009). In communal rearing, the crabs are stocked in tanks or bamboo or net cages installed in ponds. The chelipeds are removed to avoid cannibalism when the crabs molt, for although removal of the crabs' limbs could induce molting (Hopkins, 1982), this could also lead to mortalities. In individual rearing, each crab is maintained in perforated plastic boxes held in pontoons or floating platforms in a pond. When the pond is not available, the indoor crab boxes set-up with recirculating water system (RAS), as practiced in Indonesia and Malaysia, could be utilized. However, the operational expenses in RAS could be high due to the maintenance of water and power supply (FAO, 1984). In any system used, the newly molted crabs are retrieved, sorted, held in freshwater, packed, and stored in the freezer before marketing (Quinitio and Noe Lwin, 2009; Quinitio *et al*., 2015). Nonetheless, sustainable aquaculture practices should be adopted in the production of soft-shell crabs as summarized in the following:

- **Site selection**

Any brackishwater earthen pond designed for the culture of fish, shrimps, or mangrove crab can be used for the farming of soft-shell crabs. The total area needed for the culture is at least two hectares where 0.10 ha, 1.50 ha, and 0.40 ha are intended for the nursery, grow-out, and soft-shell crab operations, respectively. The criteria used to evaluate the

Box. Criteria for evaluating the suitability of a site for soft-shell crab farming

- The site should be near the source of crablets
- The type of soil should be clay or clay-loam (compact and has low permeability) which is necessary for diking and retaining water
- Brackishwater should be clean and free from sources of pollution (*e.g.* factories, food processing plants, oil depots, densely populated areas)
- The area should not be populated and protected from calamities (*e.g.* flood, siltation)
- Materials for construction of the nursery and grow-out ponds, and fabrication of nets should be available
- Ponds with several compartments should be available for the nursery of hatchery-reared crablets (2,500 m^2), grow-out compartments (5,000-10,000 m^2), and soft-shell crab production (3,000 m^2)
- Food for the stock should be available
- The electric power source should be reliable
- Transport system should be accessible (*e.g.* crablets source to farms, from farm to market)

suitability of the site for soft-shell crab farming (Quinitio *et al*., 2015; SEAFDEC-AQD *et al*., 2010) are shown in the **Box**.

- **Farming facilities**

Soft-shell crab facilities include a fully timbered roofed bridge constructed across the pond for servicing, inspection, and collection of crabs during the operation; an area for weighing, sampling, acclimation, holding newly harvested soft-shell crabs in aerated freshwater, and stocking of trays; and a freezer for storage. The demonstration farm for soft-shell crab farming at AQD's Brackishwater Station in Dumangas, Iloilo, Philippines is shown in **Figure 3**.

Figure 3. Demo farm for soft-shell crab farming at AQD's Dumangas Brackishwater Station: Working hut **(A)** connected to the roofed bridge **(B)** in the middle of the pond

(Photos: ET Quinitio)

- **Hatchery rearing of 60-100 g crab juveniles**

Outsourcing of crab juveniles from the natural stocks is discouraged to avoid further depletion of the crab population in the wild. Seed production of mangrove crabs in hatcheries could serve as good source of seedstocks. Nursery phase can be integrated into the grow-out pond for the further culture of the hatchery produced small crabs. Alternately, crab instars from the hatchery can also be stocked directly in growth ponds skipping the nursery phase as long as grow-out ponds are well prepared and no predators. Stocking of 60-100 g crabs is preferred due to shorter molt frequency than the bigger-sized juveniles. With this size, a fast recovery of investments and the production cost could be feasible. **Table 2** and **Figure 4** describe the production of 60-100 g crab juveniles for soft-shell crab farming.

- **Individual rearing of soft-shell crabs**

Scylla species with 60-100 g BW reared in the hatchery and grown in grow-out ponds are stocked individually in perforated crab boxes (**Figure 5-A**). Individual perforated plastic containers are set in PVC floating platforms called pontoons that are set in ponds (**Figures 5-B** and **5-C**). At least 5,600 crab juveniles in the intermolt and premolt stages are stocked within a month. Milkfish or siganid fingerlings can be stocked at 0.3-0.5 individuals/m^2 in the same pond compartment, as the fish can serve as 'aerators' and eat the algae that grow around the crab boxes.

The crabs are fed with wet feed such as fish and mollusks every 2-3 days at 8 % BW. Water in the pond is changed every spring tide or when necessary. Molting is monitored every 4-6 hours, and the crab has molted if two exoskeletons are present in the box. Usually, the old exoskeleton is smaller than the soft-shell crab (**Figure 6**). The hardening of the new shell starts in a few hours immediately after molting, and the crab rapidly restores its movement and defence mechanism. Thus, soft-shell crabs must be harvested immediately to retain its commercial value (Tavares *et al*., 2017).

- **Harvesting and packaging**

Newly molted crabs are transferred into a bucket containing freshwater provided with aeration. After an hour or less, the harvested soft-shell crabs can be sorted (small: < 90g BW and

Table 2. Hatchery rearing of crab juveniles for soft-shell crab farming

	Culture phase		
	Nursery	Grow-out	Soft-shell crab production (individual rearing)
Body weight, BW (g)	0.2-0.4	60-100	80-120
Carapace width, CW (cm)	1.0-1.5	6.0-9.0	7.0-11.0
Duration (day)	15-21	30-45	14-21
Culture media	Net cages in ponds	grow-out ponds	perforated boxes

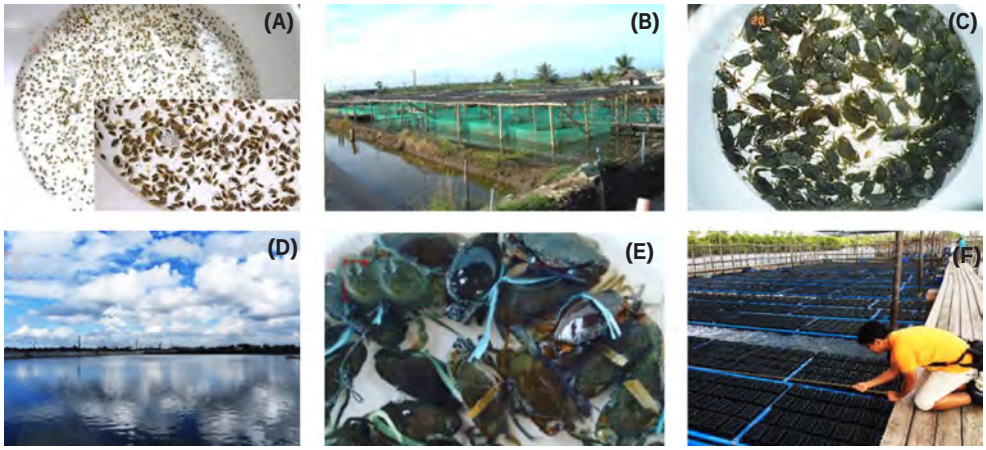

Figure 4. Production of crab juveniles for soft-shell crab farming using hatchery-sourced crab instars: **A.** crab instars; **B.** Nursery in net cages installed in a pond; **C.** 3.0-4.0 cm CW crablets; **D.** grow-out pond for stocking; **E.** 6.0-9.0 cm CW with 60-100g BW crab juveniles; and **F.** soft-shell crab production set up)

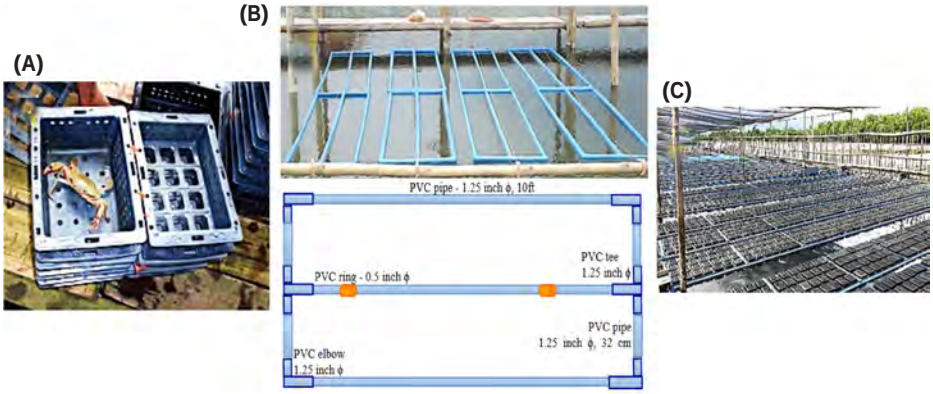

Figure 5. Set-up for individual rearing of soft-shell crab farming: **A.** individual stocking of mangrove crab in a perforated plastic container *(Photo: ET Quinitio)*; **B.** pontoons and its dimensions *(Photos: GX Libunao)*; **C.** individual setup for soft-shell crab in a pond

Figure 6. A newly molted crab juvenile and its old exoskeleton

big: > 90g BW) and packed individually in food grade plastic bag and kept in the freezer at -18 °C. For bulk orders, packed soft-shell crabs are placed in big high-density polyethylene (HDPE) plastic bag before fitting into a styrofoam box. The plastic bag is covered with used papers to maintain the cold condition of the crab in the styrofoam box, which is sealed and placed inside a bigger HDPE bag prior to shipment. The transport box must have complete details of its destination (**Figure 7**).

The Economics of Soft-shell Crab Production

Based on actual runs, the technical parameters needed for the cost and return analysis of soft-shell crab production are presented in **Table 3**. The total pond area needed for the culture is 2 ha where 0.10 ha, 1.50 ha, and 0.40 ha are intended for the nursery, grow-out, soft-shell crab, and milkfish operations, respectively. The total production of soft-shell crabs (≥ 90 g BW) is 6,150 pieces that could earn US$ 9,937.91/crop, excluding gross income from milkfish production of US$ 1,066.58/ crop. The selling prices are US$ 16.16 and 2.37, for soft-shell crab and milkfish, respectively, from the farm gate. These prices are based on the average of the existing prices for big soft-shell crabs and milkfish (4:1) in the Philippines. Nevertheless, the supply and demand chain of a particular area determines the price of soft-shell crabs.

Figure 7. Packaging of harvested soft-shell crabs: **A.** sealing in a food grade plastic bag; **B.** sorting; **C.** packing in HDPE plastic bag; and **D.** properly labeling the styrofoam box for shipping

The total investment cost, annual depreciation, and re-investment after three years for soft-shell crab farming are shown in **Table 4**. The cost of perforated crab boxes (US$ 21,202.33) constitutes 62 % of the initial investment costs. From the total variable cost of US$ 20,209.33 (**Table 5**), labor

Table 3. Technical considerations for soft-shell crab farming

Technical Parameters	Nursery	Grow-out	Soft-shell crab	Milkfish
Project duration (mo)	1.0	1.5-2.0	1.5	4
Total area of facilities for cages, ponds, tanks, and workspace (ha)	0.10	1.50	0.40	0.40
Number of crops/year	4	4	4	3
Total number of stock per crop (pcs)	24,116	14,470	7,235	2,000
Survival rate (%)	60	50	85	90
Total recovery at harvest per crop (pcs/m^2/crop)	14,470	7,235	6,150	1,800
Milkfish total harvest (kg/crop)				450
Average weight per piece at harvest (g/pc)	2-4	70-80	100	250
Cost of seeds (US$/pc)	0.13			0.13
Farm gate selling price of ≥ 90 g soft-shell crabs (US$/kg)			16.16	2.37
Gross value of harvest per crop (US$/crop)			9,937.91	1,066.58

Table 4. Investment items and costs, depreciations, and re-investment requirement for soft-shell crab production

Item	Price/unit (US$)	Quantity	Cost	Lifespan (years)	Depreciation cost/year (US$)	Re-investments on year 3 (US$)
Nursery setup	1,508.30	1	1,508.30	5	301.66	
Grow-out setup	1,077.35	1	1,077.35	5	215.47	
Pontoons	21.98	260	5,714.29	10	571.43	
Perforated crab boxes	3.45	6,150	21,202.33	5	4,240.47	
Freezer, 11 cubic feet	538.68	2	1,077.35	10	107.74	
Generator set 15kVA	538.68	1	538.68	5	107.74	
Weighing scale (50 kg)	43.09	2	86.19	3	28.73	86.19
Weighing scale (500 g)	21.55	2	43.09	3	14.36	43.09
Refractometer	280.11	1	280.11	10	28.01	
pH meter	64.64	2	129.28	3	43.09	129.28
DO meter	861.88	1	861.88	10	86.19	
Thermometer	2.15	3	6.46	3	2.15	6.46
Paddlewheel 1-unit, 1 HP	646.41	1	646.41	10	64.64	
Working area	646.41	1	646.41	8	80.80	
Electrical system	215.47	1	215.47	10	21.55	
Impulse sealer	64.64	1	64.64	5	12.93	
Other supplies	87.27	1	87.27	3	29.09	87.27
Total investment cost			**34,185.52**			**352.29**
Annual depreciation cost					**5,956.04**	

Table 5. Variable costs for soft-shell crab production

Items		Cost/crop (US$)	Annual cost (US$)
Crab instars (1-1.5 cm CW)		3,117.78	12,471.11
Milkfish juveniles (10-15 g)		258.56	775.69
Feed	Nursery	20.75	83.00
	Grow-out	128.30	513.22
	Soft-shell crab	312.76	1,251.04
	Milkfish	91.58	274.73
Chemicals for Pond Preparation		107.74	107.74
Labor, 2 technicians at US$ 7.54/d		904.98	3,619.91
Gasoline for generator set		64.64	265.57
Other supplies		265.57	531.14
Total		**5,272.66**	**20,209.33**

Table 6. Fixed costs for soft-shell crab production

Items	Cost/crop (US$)	Annual cost (US$)
Pond lease	242.40	969.62
Maintenance and repairs (2 % total cost)	170.93	683.71
Depreciation costs	1,489.01	5,956.04
Interest on investment (12 %/yr)	1,025.57	4,102.26
Total fixed cost	**2,927.91**	**11,711.64**

Table 7. Cost and return analysis of soft-shell crab and milkfish production

Economic efficiency indicators	Per crop (Soft-shell Crabs)	Per crop (Milkfish)	Per year
Gross revenue (US$)	9,937.91	1,066.58	42,951.39
Net income (US$)			11,030.42
Return on investment (ROI, %)			32.27
Payback period (years)			2.01
Break-even price of soft-shell crabs (US$/kg)			12.98

is found to be more expensive than any other items. It must be noted that monitoring of nursery and grow-out operations would require labor force, thus, in the production of crab juveniles and soft-shell crabs, the labor cost would usually comprise about 18 %.

Table 6 shows the yearly fixed cost for soft-shell crab production which amounts to US$ 11,711.64. Thus, the total production cost (variable costs + fixed costs) is US$ 8,200.56/crop or US$ 31,920.97/year, given that four runs are conducted annually. Also, it must be considered that labor and material cost would differ in every region. Based on the production technology efficiency indicators (**Table 7**), soft-shell crab farming using crab juveniles from the hatchery seeds is a feasible enterprise. The initial investment could be recovered within 2.01 years with an annual net income of US$ 11,030.42.

Dissemination of Technology on Soft-shell Crab Production

The soft-shell crab production technology was disseminated to interested crab growers, businessmen, and other stakeholders through the regular training course on mangrove crab nursery and grow-out operations at SEAFDEC/AQD. This has enabled

four private sectors in the country, namely: Aquascapes in Cavite, RC2 Aquaventures in Palawan, Ragus Soft-shell Crab Farm in Iloilo, and Tuason Crab Culture in Davao del Norte to produce soft-shell crabs for local consumption. The Philippine Bureau of Fisheries and Aquatic Resources (BFAR) in Pagbilao, Quezon has also adopted the technology of SEAFDEC/AQD with slight modifications.

Conclusion and Way Forward

Through the application of responsible aquaculture, the production of soft-shell crab using hatchery-produced seedstocks would be sustainable, and the technology introduced by SEAFDEC/AQD can be easily adopted. The Philippines and other countries engaged in soft-shell crab farming should source their seedstocks from the hatcheries to avoid dependence on wild resources.

Presently, an ongoing study is being conducted at SEAFDEC/AQD adopting the use of spinach extract to hasten the molting of mangrove crab in laboratory scale prior to the application in the farm set up. Spinach extract, a good source of phytoecdysteroids (Schmelz, Grebenok, Ohnmeiss, & Bowers, 2000), has been tested to induce molting in crabs (*Scylla olivacea*, *Portunus pelagicus*) (Aslamyah and Fujaya, 2011; Fujaya, 2011; Sorach Pratoomchat, Hanna, and Suksamrarn, 2013). Phytoecdysteroid, an ecdysteroid-analog that is found in plants was proven to hasten molting in crustaceans (Aslamyah and Fujaya, 2011; Dinan, 2001; Fujaya, 2011; Putchakarn, 1991; Sorach et.al., 2013; Tamsil, Yasin, & Fujaya, 2015). Thus, this project would aim to address one of the problems encountered in soft-shell crab farming, which is the asynchronous molting of crabs, thereby, prolonging the duration of culture and staggered harvesting of soft-shell crabs.

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