Review

Nursery Culture of Mud Crab, Genus *Scylla*, a Review: The Current Progress and Future Directions

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Simple Summary: Increasing scarcity of limited culture techniques for future aquaculture candidates especially for portunid crab species is still unclear. Thus, nursery culture knowledge is important for successful commercial seed production, especially for the highly delicacy mud crab, genus *Scylla*. The aim of this review paper is to summarize the status and information on the current nursery culture stage of *Scylla* mud crab. Various aspects of mud crab hatchery that described in this paper are expected to make it easier for practitioners or lay people to understand mud crab nursery easily. This study is also expected to provide motivation to researchers in conducting research and development on mud crab nursery in the future so that the production of mud crab crablets from the hatcheries can be increased and profitable.

Abstract: This study attempted to explain the definition, objectives, and key stages in mud crab nursery activities. The nursery stages of *Scylla* spp was started from megalopa stage to several crablet instar stages or started from earlier crablet stage to several crablet stages. Direct stocking of megalopa into ponds is not recommended due to their sensitivity. Instead, nursery rearing is needed to produce mud crab of larger size before stocking. Individual nursery rearing results in higher survival rate (up to 100%), but with reduced growth rate, and a more complicated maintenance process compared with communal rearing. Nursery of mud crab can be done indoors, or outdoors, with adequate shelter and feed required to obtain good survival and growth performance. *Artemia* nauplii are the main, established nursery feed, particularly at megalopa stage, while survival rate may be improved if combined with artificial feed, such as micro bound diet formulations. Water quality parameters, identical to those proposed in tiger shrimp culture, can followed. Crablets may be transported to the pond location with, or without water. The provision of monosex seeds from mud crab hatcheries is expected to become more common, increasing seed price, and thus improving income of farmers. Numerous aspects of mud crab nursery, including nutrition, feeding strategies, understanding of their behaviour, i.e., cannibalism, control of environmental factors, and practical rearing techniques, still need further improvement.

Keywords: aquaculture; shellfish; future food; nursery stage; mud crab; juvenile; seed production; hatchery; crablet; breeding

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1. Introduction

Mud crab is one of the favorite seafood products both local and international markets [1,2]. The demand for this species increases annually [3], which has led to overfishing, as most mud crab landings still rely heavily on captured fisheries [4,5]. The impact on wild populations could be lessened, if sufficient support were received from the aquaculture

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sector in the form of seed supply from hatcheries [2,6,7]. As well, mud crab grow-out and fattening activities incorporated within the mangrove area, known as silvo-fishery techniques [8,9,10], culture in earthen ponds [11,12] or in concrete ponds [13], and grow-out activity in indoor conditions [14,15], could all contribute to hatchery replacement of wild catch. However, mud crab hatchery activities continue to be constrained by low survival rates, hence the supply of seeds is still very limited for large-scale aquaculture purposes [2,16]. Disease control and improved nutritional condition of larvae in seed production tanks also need to be developed, for reliable mass seed production of portunid crabs to be implemented [17].

Mud crab hatcheries typically involve maintenance of larvae to crablet size (>5 mm) before marketing to farmers [18,19]. Maintenance of mud crab larvae in the hatchery has three stages, namely the Zoea 1 (Z1) to Zoea 5 (Z5) larvae, Z5 to Megalopa (M), and the maintenance of M to crablet phase [20]. The hatchery production process of mud crab crablet takes about 30 days (starting from Z1 to Crablet 2-3 (C2-C3)) [21]. The crablet production period for mud crabs is longer than that of blue swimming crab, *Portunus pelagicus*. This is because the zoea mud crab phase consists of 5 phases, being more than undergone for *P. pelagicus,* and the duration for each phase of the zoea is longer (3-4 days) compared to *P. pelagicus* (2-3 days) [22].

Unlike *P. pelagicus*, where high survival has been observed when stocking into ponds at the megalopae phase, the critical transition step of megalopa to Crablet 1 (C1) in mud crabs has typically produced inconsistent and unreliable results, with high mortality often reported during metamorphosis from megalopa to C1 stage [23,24]. Therefore, the nursery phase of mud crab (from megalopae to early crablet stages (≥C3)) needs to be improved to a large number of high qualities crablets [17,25,26]. The larval rearing process was thoroughly reviewed by Waiho et al. [2], while the current review is focused on rearing techniques, and parameters involved in the nursery phase of mud crab, genus *Scylla*, including principal technical practices of mud crab nursery, from stocking to transportation, and some issues during this phase are identified and potential solutions discussed.

2. Mud Crab Culture Nursery Stages

The nursery stages of mud crab, genus *Scylla*, include one megalopa stage, and subsequent crab instar stages. The transition from megalopa (M) into the C1 stage is around 6-7 days [24]. Maintenance of megalopa stage to the 1st crablet instar (Crablet 1 stage (C1)) is one of the most critical periods of mud crab larvae rearing. Among the assumed bottle necks of this phase are; (i) nutritional factors that trigger the occurrence of Moulting Death Syndrome (MDS) [27], and (ii) high cannibalism level, since M is the first stage when pincers appear [28,29,30]. Maintenance of M to C1 of mud crabs requires more serious attention because the survival rate remains very low (<50%) and is inconsistent. Studies related to nutritional, environmental, and behavioural aspects at this phase are needed to optimize seed production from hatcheries. Aside from megalopa to the crablet phase, extended nursery stage of mud crabs is done to produce larger size of young crabs [29,31,32].

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Zoea 1 (Z1)
(zoea phase has 5 stages (Z1-Z5))

Megalopa phase

Crablet3 (C3)

Figure 1. Larvae development of mud crab from Zoea to Crablet stages

3. Mud Crab Nursery Techniques

3.1. Nursery Area

Nursery area may be located indoors or outdoors. Nursery area may be located indoors or outdoors. M are nursed in concrete tanks, fiberglass or plastic tanks, or net cages within brackishwater ponds (Table 1) [24,25,28,32,33]. The nursery of mud crabs in indoor conditions allows for easier control of various parameters, e.g., water quality control, water exchange, siphoning of waste and excess feed, as well as improving access for daily observation of crablets. However, the production and growth of crablets in net cages, or in ponds, has shown better results [33]. Natural lighting, accompanied by the presence of natural food in ponds, are believed to be the trigger factors for the growth of crablets maintained in net cages.

The nursery of mud crabs in indoor conditions will still need to be further investigated, to optimize production of crablets from hatcheries. Among the methods that can be applied to indoor mud crab protocols is biofloc technology. Research will need to determine if biofloc water from shrimp farming industry waste may be used as an alternative medium for future M maintenance, and whether feed, in the form of biofloc flour, can be an alternative feed for M and crablet.

3.2. Rearing Techniques

Another important consideration is whether to rear individually, or communally. Nursery rearing of M individually, in good water quality condition, could raise survival up to 90-100% [26,34]. Although a high survival rate is valuable, extra effort is required to implement the individual crablet rearing technique, especially during feeding. Automatic feed machines during individual M rearing could be developed to have low capital and operating costs, to reduce high manpower cost and inefficiency of manual feeding.

In the communal rearing technique, canibalism is a major problem. To reduce cannibalism, black nylon, bunched netting, or seaweed may be placed at the bottom of rearing tanks, as shelters, while some may also be allowed to float in the water column [24,32,35,36]. During crablet or juvenile stages, shelter options include plastic strings, bamboo tubes, and open sand substratum [35], or brick and shell shelters [29]. The presence of shelters and the availability of sufficient feed greatly reduce the rate of cannibalism [37], which is reasonable, since decapod larvae usually associate with floating leaves and clumps of algae in natural conditions, and this behaviour could reduce predation, save energy when close to the turbid water surface, or function as a transport mechanism [38]. Some studies related to the nursery of mud crab started at megalopa and crablet stages is presented in Table 1.

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Table 1: Some studies related to the nursery of mud crab started at megalopa and crablet stages

Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
M to C1 (*S. serrata*)	Feeding regimes: **(a)** *Artemia* nauplii, **(b)** boosted *Artemia*, **(c)** dried shrimp (*Acetes*spp) and **(d)** dried mud worm (*Marphysa* spp)	10 ind.L^{-1}	Bowl of 5 L volume (filled 3 L culture water)	none	**(a)** **(b)** **(c)** **(d)** **(a,b)** **(a,c)** **(a,d)** **(b,c)** **(b,d)** **(c,d)**	Until M metamorphosed to crabs or died	**38.9** **46.7** **12.8** **6.7** **49.4** **40.0** **57.8** **45.6** **41.7** **6.1**		[16]
M to crablet stages (*S. serrata*)	Stocking density	**10 ind/m^2** **20 ind/m^2** **30 ind/m^2**	Net cages	Dried coconut fronds	Macerated brown mussel meat (*Modiolus metcalfei)* or fish (20-30% of biomass)	30	**53.33** **48.30** **50.00**		[28]
M to crablet stages (*S. serrata*)	**Salinity 26 ppt** **Salinity 32 ppt**	1000 ind/m^3	Concrete tanks and net cages	PVC pipe cuttings, black nets, and seaweed *Gracilariopsisbailinae*	*Artemia* nauplii, adult artemia, trash fish, green mussel, or *Acetes*	18	**40.10** **26.20**		[39]

Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
M to C1 (*S. serrata*)	Feeding regimes	12 ind.L^{-1}	Tall conical-based plastic	none	**100% MBD**	Until M metamorphosed to C1or died	**±6.5**		[40]
					100% *Artemia*		**±5.0**		
					75%MBD:25%*Artemia*		**±5.0**		
					50%MBD:50%*Artemia*		**±3.5**		
					25%MBD:75%*Artemia*		**±8.5**		
M to C1 (*S. serrata*)	Feeding regimes	Individually	Round flat-bottomed plastic	none	**100% MBD**	Until M metamorphosed to C1or died	**90**		[40]
					100% *Artemia*		**90**		
M to C1 (*S. serrata*)	Feeding regimes: Microbound diets (MBD)	Individually	Flat-bottomed circular aquaria (250 ml)	none	**MBD (prepared using dried rotifers)**	Until M metamorphosed to C1 or died	**46.67**		[41]
					MBD (prepared using *Artemia* meal)		**46.67**		
					MBD (prepared using squid meal)		**60.00**		
					MBD (prepared using fish meal)		**60.00**		
					Live *Artemia*		**80.00**		

Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
M to C1 (*S. serrata*)	Feeding regimes: MBD prepared using squid meal (containing different levels of dietary cholesterol)	Individually	Flat-bottomed aquaria (250 ml)	none	**MBD + 0.14% cholesterol level**	Until Mmetamorphosed to C1or died	**26.70**		[42]
					MBD + 0.20% cholesterol level		**60.00**		
					MBD + 0.40% cholesterol level		**53.30**		
					MBD + 0.80% cholesterol level		**73.30**		
					MBD + 1.00% cholesterol level		**46.70**		
					Live *Artemia*		**53.30**		
M to C1 (*S. serrata*)	Feeding regimes: MBD (containing various levels of supplemental dietary lecithin and cholesterol)	Individually	Flat-bottomed aquaria (250 ml)	none	**MBD (containing lecithin 5.5 $g.kg^{-1}$ + cholesterol 0.3 kg^{-1})**		**20**		[43]
					MBD (containing lecithin 5.2 $g.kg^{-1}$ + cholesterol 7.9 kg^{-1})		**27**		
					MBD (containing lecithin 23.1 $g.kg^{-1}$ + cholesterol 0.1 kg^{-1})		**33**		
					MBD (containing lecithin 27.8 $g.kg^{-1}$ + cholesterol 10.7 kg^{-1})		**53**		
					MBD (containing lecithin 39.7 $g.kg^{-1}$ + cholesterol 0.6 kg^{-1})		**60**		
					MBD (containing lecithin 44.1 $g.kg^{-1}$ + cholesterol 8.8 kg^{-1})		**60**		
					Live *Artemia*		**60**		

Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
M to C1 (*S. serrata*)	Feeding regimes: MBD (containing various fish oil:corn oil ratios)	Individually	Flat-bottomed circular aquaria (250 ml)	none	**MBD (fish oil:corn oil = 0:1)**	Until M metamorphosed to C1 or died	**35**		[44]
					MBD (fish oil:corn oil = 1:2)		**55**		
					MBD (fish oil:corn oil = 2:1)		**60**		
					MBD (fish oil:corn oil = 3:1)		**65**		
					MBD (fish oil:corn oil = 1:0)		**65**		
					MBD (fish oil:corn oil = 1:1)		**70**		
					Live *Artemia*		**60**		
Z5 and M (mix) to C2-3 (*S. serrata*)	Feeding regimes	133 ind/m^2	Aquarium	Paranet pieces	***Artemia* nauplii only**	**14**	**26.66**		[20]
					***Artemia* nauplii + PL shrimp feed**		**31.66**		
					***Artemia* nauplii + dried shrimp**		**20.00**		
					***Artemia* nauplii + shrimp feed**		**11.66**		

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Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
M to crablet stages (*S. paramamosain*)	**Temp. 20ºC**	Individually	Plastic cup with diameter of 6-9 cm	none	Frozen *Artemia* nauplii, Frozen Adult *Artemia*,andartificial feed	45	**0**	**0**	[26]
	Temp. 24ºC						**86.67**	**3.74**	
	Temp. 28ºC						**96.67**	**4.50**	
	Temp. 32ºC						**80.00**	**3.95**	
	Temp. 36ºC						**0**	**0**	
	Temp. Ambient (27-30ºC)						**93.33**	**4.38**	
M to C1	Feeding regimes	Individually	Plastics beakers (0.5 L)	none	Live *Acetes* (LA) Minced Shrimp Meat Locally Formulated Feed Commercial feed LA + MSM LA + LFF LA + CF	Until M metamorphosed to C1 or died	85-100		[45]
M to C1	Feeding regimes	Communal	Earthen dugout holes 60x60x20 cm		Live *Acetes* (LA) Minced Shrimp Meat Locally Formulated Feed Commercial feed LA + MSM LA + LFF LA + CF	10	47.9-87.5		[45]

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Initial stage of mud crab (*Scylla* spp)	Treatment	Stocking density	Rearing medium	Type of shelter	Feeding	Rearing duration (days)	SR (%)	SGR_{CW} (%)	Reference
C1 to several crablet stages	Stocking density	**110 ind/m²** **175 ind/m²** **230 ind/m²**	PVC containers	Sand substrate	*Artemia* biomass and chopped peeled shrimp	15	**71.3** **61.7** **57.5**		[29]
C1 to several crablet stages	Shelter	**110 ind/m²**	Cement tank	**Clay brick** **Without clay brick**	Peeled shrimp	**17**	**25.3** **13.5**		[29]
C1 to several crablet stages	Shelter types	**100 ind/m²**	Composite tank	**Bricks** **Clam shell** **Without shelter**	Peeled shrimp	**21**	**40** **41** **30**		[29]
Crablets of 7-10 days old (±C3) (*S.olivacea*)	Rearing medium	50 ind/m²	**Fiber tank** **Hapa net**	Paranet pieces	*Acetes* spp	21	**21.33** **37.33**		[32]

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3.3 Seed Stocking

3.3.1 Stocking Strategies

The stocking density of 3-5 days-old M in nursery tanks is typically around 2,000-4,000/m^3 (1000-2000/ton) of water [24,25]. Based on the habit of megalopa stage crablets to go down to the bottom just before moulting to C1, the recommended stocking technique for M is based on area (ind/m^2). Further study related to the optimal density of M per unit area needs to be carried out in future. Stocking of M with densities of 10, 20, 30 ind/m^2 in net cages within earthen ponds was shown to attain an average 50.5% survival rate [28], while rearing of M in an aquarium with a density of 133 ind/m^2 had a survival rate between 11.7-31.7%, although on different feeds [20]. Besides stocking density, another factor that needs to be considered, to determine stocking density of M, is optimal water depth that can be used during the maintenance process.

When C1 was cultured at high densities of 110, 175, and 230 crabs/m^2 for 15 days, survival rates of 71%, 62% and 58% were reported, respectively [29]. Longer nursery period of 30 days with lower density of 70 ind/m^2 had a survival rate of 52-66%, while further extended nursery to 60 days with a density of 30 ind/m^2 attained a survival rate of 64-67% [29]. A lower survival rate of between 21 and 37% was found by Syafaat et al. [32], for mud crab crablet (Day 7-10) reared for 21 days at a density of 50 ind/m^2. Hence, further research is needed to identify the factors controlling survival rate, in relation to stocking density.

3.3.2 Age of Megalopa

The age of M at moulting is likely to affect moulting success of M to C1. Syafaat [26] reported a lower survival rate of 2-3 day megalopa, than for 5-6 day during their molt from M to C1 (reared individually). In communal culture condition, using *hapa* nets within earthen pond of 80 cm water depth, older M (3 and 4-day) showed better survival than Z5, 1-day old, and 2-day old M [46]. A side from cannibalism and other factors, such as environmental conditions, feed nutrition, and disease, age of M at stocking is another factor that needs to be considered in order to maximize survival from M to C1, particularly under an individual culture condition.

3.3.3 Transportation of Megalopa

During transportation, avoidance of a stationary transport condition, or continuous agitation, has been indicated to reduce the probability of M to grasp each other ([47]. Transportation of M is typically in plastic bags with density of 200-300 ind/L [28]. Survival rate is usually lower at higher density. For example, Quinito and Parado-Estepa [47] reported that survival of M over a 6-h simulated transport (including shaking) could reach 99.3±1.6%, 93.0±5%, and 94.0±3.8% for densities of 50, 100 and 150 ind/L, respectively, leading to a conclusion that lower density, i.e., 50 ind/L, is preferable. Besides density, temperature also affects survival rate of M during transportation. Survival during transport of M at a temperature of 28°C was lower than at a temperature of 24°C [47].

3.4 Feeding Strategies

Artemia is often used as the main feed during the maintenance of M to crablet stages, with additional dried shrimp, dried mud worms, prawn/shrimp meat, fish meat, or artificial feed (shrimp larvae feed) being added as high as 1-5 mg/L concentration (Table 2) [16,20,48,49]. Chen et al. [50] clarified that M were able to capture prey whose sizes ranged from nauplii up to small adult *Artemia*. Apart from suitable feed size, feed nutritional quality is another important component supporting development of M into C1 stage. The use of enriched *Artemia* (instar 2) resulted in better survival than use of only *Artemia* nauplii [16]. *Acetes* is a potential live food in mud crab nursery from megalopa to crablet stage. The rearing of megalopa on *Acetes* alone, or combined with minced shrimp meat, locally formulated feed, or commercial feed, showed better survival than treatments fed with minced shrimp meat, locally formulated feed, or commercial feed alone [45]. It is recommended to start artificial feed supplementation at the M stage, as diet modulation of gut evacuation time (GET) is expected to begin at this stage [51], while digestive enzyme activity of mud crab larvae tends to increase with increasing larval stage [52,53].

Supplementation with artificial feed (shrimp post larvae feed), and *Artemia*, showed higher survival rate when compared to treatment being fed *Artemia* alone, in rearing from the Z5 and M stages [20,49]. The use of juiced artificial feed, with added spirulina powder and digezym (containing amylase, protease, lactase, and selulose), together with *Artemia* nauplii, produced more C1 than treatment being fed only artificial feed juice (without spirulina powder and digezym), and *Artemia* nauplii [54]. Shorter moulting intervals shown in M fed only with Microbound Diet (MBD), or MBD combined with *Artemia,* suggested that MBD may contain beneficial nutrients not provided by *Artemia* [40], which have been evaluated as Eicosapentaenoic acid (EPA) and Docosahexaenoic Acid (DHA) [16,55,56] and as lipid profile [44].

The low content of both EPA and DHA in rotifers and *Artemia* could affect the vitality of larvae [53,57,58]. Inappropriate lipid profile for marine crustaceans, found in rotifer and *Artemia* nauplii, could affect both larval development and survival of mud crab larvae [44]. MBD feed, containing squid meal with proper cholesterol and lechitin levels, provides the equivalent survival of megalopa and can even be better than diet of only live *Artemia* [41,42,43]. Further, MBD feed containing a fish oil to corn oil ratio of as high as 1:1 showed a better survival of M, compared to treatment that was fed only *Artemia* nauplii [44].

As soon as M metamorphose to crab stage, they are fed with minced trash fish, green mussel, *Acetes* [39], fresh chopped shrimp or tilapia [29], brown mussel [59], frozen adult *Artemia* [26], or artificial feed [20,21].

Table 2: Feeding strategies at megalopa and crablet stages of mud crab

Mud crab stages	Type and dosage of feed		Feeding Frequency (times/day)	Reference
	Artemia nauplii	Additional feed		
Megalopa to crablet instar (C1)	5-30 ind.ml^{-1}	Macerated prawn abdomen	1	[48]
Megalopa to crablet	0.75 ind.ml^{-1} (*Artemia* nauplii) 0.5 ind.ml^{-1} (boosted *Artemia*)	Dried shrimp (*Acetes* spp) and dried mud worm (*Marphysa* spp) (5 mg/L)	N/A	[16]
Megalopa to crablets	3-5 ind.ml^{-1}	Trash fish, green mussel or *Acetes* spp (given when megalopa metamorphosed to crab stage)	2	[39]
Megalopa to crablets	N/A	Macerated brown mussel meat (*Modiolus metcalfei*) or fish (20-30% of biomass)	3	[28]
Megalopa to crablet instar	N/A	MBD (with different formulations)	2	[40,41,42,43,44]
Zoea 2 to crablet 1	4 × 5 g/tank (1m^3) /day	Artificial feed juice (3 × 5 g/tank (1m^3) /day)	3-4	[54]

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Zoea 5 and Megalopa to crablets	N/A	Shrimp larvae feed	N/A	[49]
Megalopa to crablets	3-5 ind.ml^{-1} (enriched Artemia nauplii)	Shrimp meat and shrimp larvae feed	2	[21]

*N/A: Not available

4. Water Quality

Water quality conditions tolerable in both larval rearing, and brood stock maintenance of mud crab include 28-35 ppt salinity (10-35 ppt for nursery and grow out), temperature of 27-32^{o}C , pH of 7.5-8.5, DO >4 ppm, and ammonia <0.01 ppm [60]. Alkalinity >80 ppm has been suggested for mud crab farming (ideally 120 ppm) [61]. As the optimal water parameters for mud crab farming are still considered to be under development, optimal water parameters for tiger prawns may be used as guidance (Table 3) [61].

Temperature and salinity are the two main parameters to be considered routinely both in larvae rearing, and nursery phases of mud crab [26,31,34,62,63,64,65]. These two parameters greatly affect physiological processes, having an impact on the growth of portunid crab [22,66,67]. The recommended salinity for the rearing of M and C1 is between 20-25 ppt [31,34,62,63,64,65], while recommended temperature is 28-30^{o}C [26,31,66]. The optimal temperature recommended for the moulting process of M to C1 is 28^{o}C, with a lower temperature condition between 24 and 28^{o}C having been shown to be more conducive to the moulting process of M to C1, much preferred to high temperature (i.e., up to 32^{o}C), or fluctuating temperature conditions [26].

The use of artificial feed during mud crab larvae rearing may trigger the growth of *Vibrio* spp. on culture media [21]. Hence, the use of antibiotics (which are only allowed according to the rules of individual countries) to control the growth of *Vibrio* spp. is still needed. However, the rearing of portunid crab larvae with probiotics has been proven to improve production of mud crab crablet [26], and is able to suppress and control the development of pathogenic of *Vibrio* spp. populations [3,68], where by their use is recommended over the use of antibiotics.

Table 3: Water quality parameters that suggested for mud crab culture operation

Parameters	Optimum range / value	Sampling frequency
Dissolved oxygen (DO)	>5 ppm* (mud crab is tolerant in low oxygen level)	Twice a day
pH	7.5 – 9; <0.5 daily variation with 7.8 is optimum value	Twice a day
Temperature	25-35 ^{o}C (Max and Min)	Weekly
Salinity	10-25 ppt for crablet	Weekly
Total ammonia nitrogen (TAN)	<3 ppm* (crablet has tolerance to high ammonia)	Daily observation is needed
Un-ionized ammonia (NH_3)	<0.25 ppm* (crablet has tolerance to high ammonia)	Daily observation is needed
Nirite (NO_2)	<10 ppm at salinity >15 ppt ; <5 ppm at salinity <15 ppt	Daily observation is needed
Alkalinity	>80 ppm (ideally 120 ppm)	Daily observation is needed
Hardness	>2000 ppm*	Daily observation is needed
Hidrogen sulfida	<0.1 ppm*	Weekly
Turbidity	20-30 cm*	Daily

*Range for *Penaeus monodon* (used to provide information for farmers)
Source: [61]

5. Harvest and Transportation of Crablet

The harvesting process for the nursery phase (M to crablets, or from early crablets (C1-C2) to larger crablets phase) occurs between 2 and 4 weeks after stocking. Long nursery periods in small areas (high density, with minimal shelter), will lead to high mortality due to cannibalism. Two methods, the dry (moist) method [19,69], and the wet method (with water) [70] can be used to deliver harvested crablets to grow-out farms (Table 3). The dry method of transportation, without water, uses materials that function as shelter within containers. The wet method provides water, typically in a plastic bag, and supplied with sufficient oxygen above the water. Shelter is also a requirement of wet method transportation, i.e., nylon net.

Table 3: Literature related to transportation of mud crab crablet

Life stage of mud crab (days / sizes)	Crablet (D20) *Scylla paramamosain*	Crablet (with width carapace less than 1 cm) *Scylla paramamosain*	Crablet (D37) *Scylla tranquebarica*
Methods	Wet	Dry (without water)	Wet
Medium	Plastic bags (filled with oxygen)	Plastic bags (filled with oxygen)	Styrofoam box (40x50 cm)
Density	50, 100, 150 ind/pack	200 & 300 crablet	700 ind/box
Shelter	A nylon net (20x40 cm)	Wet cloth along with seaweed (*Gracillaria* spp.)	Paranet
Duration (hour)	5	5	6
Survival rate (%)	88-97	98-99	>95
Reference	[70]	[69]	[19]

6. Sex Differentiation in Crablet Stage

Morphological sex differentiation of mud crab is based on the shape of the abdominal flap in the earlier crablet stages, i.e., for *S. paramamosain*, and can be seen clearly at C5 stage (CW of ±1 cm) using a microscope (magnification of 8-20x), whereas the difference can be seen with the naked eye in the ±C9 stage (CW of ±2 cm) [26]. In mud crab, *S. serrata*, the different shape of the male and female abdomen enables sexing of crabs above 3 cm carapace width with casual inspection, while below this size sex can be determined at 30x by means of a binocular microscope [71]. Females are recognized by the presence of 4 pairs of biramous pleopods, and oviduct depression on the sternites of the 6th thoracic segment, while males are recognized by the presence of copulatory pleopods, and the absence of oviduct depressions [71].

The ability to distinguish the sex of mud crabs in the crablet phase can be an added value for mud crab hatcheries, allowing sale at a higher price. In mud crab culture, monosex culture is highly profitable as mud crab shows obvious sexual dimorphism. Monosex culture of all male shows higher Specific Growth Rates (SGRs) compared to all female [9], and culture trial of mono-sex culture (all male and all female) has yielded significantly higher production and survival compared to the mixed culture [72]. Therefore, availability of monosex seeds is also important to support monosex mud crab farming in brackishwater ponds. Further study on sex reversal technology for mud crab to produce mono sex crab seeds is important to conduct in the future.

7. Conclusion and Recommendations

Mud crab nursery in the hatchery, beginning from the M stage, is important to production because the stocking of M directly to ponds has not shown good results, when compared with species such as *P. pelagicus*. Although operating mud crab nursery for crablets individually exhibits higher survival, when compared to communal rearing, the individual nursery involves higher complexity, and resourcing, so that it will be necessary to consider rearing technology using automatic machinery, especially for the feeding process. Mud crab nursery can be carried out both indoors (using plastic, fiberglass, or concrete tanks), and outdoors (earth, lined, or concrete ponds) within net cages. In all applications, rearing needs to be accompanied by the use of adequate shelter, particularly for communal nursery.

Availability of adequate food is one of the main things to be considered to suppress cannibalism. Feed in the form of live *Artemia* is still the most common, main feed in the M phase, but *Artemia* combined with additional feed (artificial feed, worn meal, shrimp meat) provides better survival compared to *Artemia* alone. MBD of the right composition is a feed candidate to replace or substitute for *Artemia* in the M phase.

Although mud crabs are believed to show good resilience in nature, and survive in extreme conditions (e.g., in mud, and without water), water quality parameters for shrimp culture can be used as a guide in mud crab farming activities. Studies related to the transportation of crablet still need to be carried out to produce practical, inexpensive methods, and to determine the extent of crablet resistance during transportation without water. In addition, improved knowledge of sex differentiation of mud crab during early crablet stage would be expected to provide added value to mud crabs hatcheries.

Various aspects of mud crab hatchery that are described in this paper are expected to make it easier for practitioners to understand mud crab nursery operations. This study is also expected to provide motivation to researchers in conducting research and development on mud crab nursery in the future, so that the total production of mud crab crablets from hatcheries can be increased, and also become more profitable.

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