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Systems and techniques used in the culture of soft-shell swimming crabs

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Abstract

The academic interest in the production of soft-shell swimming crabs has increased in direct proportion to the increasing demand worldwide for this gastronomic delicacy. The techniques of obtaining this product are essentially based on the maintenance of swimming crabs at premoult stage in open, semi-closed or closed farming systems, until the moment of moulting. These different types of systems reflect the biological e environmental control method evolution. To achieve industrial scale production of soft swimming crabs, the option of using closed systems has increased in recent years. This type of system offers several advantages, such as greater control over environmental variables, greater ease of installation, higher storage densities, greater ease of monitoring ecdysis occurrence and, especially, the possibility of incorporating several forms of automation. In this review, the main production systems currently used, as well as the main techniques for obtaining the animals, their management under controlled conditions, harvesting and slaughter, are presented and discussed, focusing on future perspectives for the world production of soft-shell swimming crabs.

Key words: aquaculture, ecdysis, enclosure, pond, recirculation system, swimming crab.

Introduction

Swimming crabs (Decapoda: Portunidae) are known for their great aquaculture potential (Mwaluma 2002). One of the most profitable forms is their commercialization as 'soft-shell' crabs (Perry *et al.* 2010; FAO, 2015; He 2015).

The term 'soft-shell' does not refer to a particular species of crab but to a stage of the growth cycle of any species of crab when they undergo the ecdysis process, in which its old hard exoskeleton is shed and replaced by a new, decalcified, hydrated and thus briefly soft exoskeleton (Aiken 1969; Freeman & Perry 1985). During this short period, it is known as 'soft-shell' crabs (Freeman & Perry 1985; Freeman *et al.* 1987). After only a few hours, the exoskeleton begins a hardening process, quickly restoring the animal's defence ability and locomotion (Cameron 1985; Perry *et al.* 2001), losing its commercial value.

If caught shortly after moulting, the crabs can be consumed whole, which makes them a much appreciated delicacy. Owing to their gastronomic interest, soft-shell swimming crabs can be sold up to seven times the price of hard-shell swimming crabs (Malone & Culley 1988; Wickins & Lee 2002; Cap Log Group, 2012).

Although less than 714 species of Portunidae (GBIF, 2016) are known, only a few species of swimming crabs are regularly marketed as soft-shell crabs in the world (Kennedy & Cronin 2007). Species such as *Scylla serrata* (Paterson & Mann 2011; Shelley & Lovatelli 2011; Hasan & Zafar 2013), *Portunus pelagicus* (Azra & Ikhwanuddin 2015) and *Callinectes sapidus* (Oesterling 1988), are the most cultivated mainly because of their abundance and cultivation simplicity.

The commercial exploitation of soft-shell swimming crabs in the United States is more than 150 years (Roberts 1905; Oesterling 1988) and a little over 100 years in Asia (Yalin & Qingsheng 1994). According to Oesterling (1993), the production of soft-shell swimming crabs may have been one of the first forms of culture of aquatic organisms in the United States. According to the author, the animals were already consumed by Native Americans. Initially, soft-shell swimming crabs were obtained incidentally through fishing and were kept in simple fencing systems until ecdysis. With the arrival of the English settlers in America, this consumption was rapidly popularized, but it would still take hundreds of years for the first attempts of commercial production of soft-shell swimming crabs.

Since then, controlled production of soft-shell swimming crabs has always been on the rise due to the advances of production technologies and the increased world demand, transforming soft-shell swimming crab farming into an effective component of the seafood industry (Ferdoushi *et al.* 2010; Gaudé & Anderson 2011).

Currently, catches for the production of soft-shell swimming crabs are no longer accidental. There is a type of fishing specifically dedicated to the catch of swimming crabs. More specifically efforts are made to collect crabs that show indicative signs of the proximity of the ecdysis period, although still in the premoult stage (Perry *et al.* 2010; Primavera *et al.* 2010; Gaudé & Anderson 2011; Shelley & Lovatelli 2011; Songrak *et al.* 2013). The selected animals are then transferred to the cultivation facilities where they are kept under controlled environmental conditions until ecdysis (Newcombe 1945; Cameron 1985; Oesterling 1988; Kennedy & Cronin 2007; Perry *et al.* 2010; Gaudé & Anderson 2011).

In this study, the systems used for the production of soft-shell swimming crabs in different parts of the world and the main techniques of collection, management and slaughtering are described, as a basis for analysis of the perspectives of the world production of soft-shell swimming crabs.

Soft-shell swimming crab farming systems

The major common points among the main systems currently used for soft-shell swimming crab farming are the confinement of the animals in the premoult stage (Gaudé & Anderson 2011) and the requirement that the place used to keep the animals allows an easy monitoring of the ecdysis as well as fast removal of the recently moulted animals (Oesterling & Moore 1995).

Based on these common features, soft-shell swimming crab farming systems can be divided into three groups: open systems, carried out in continuous coastal areas such as bays, coves or lagoons; semi-closed systems, undertaken in ponds, similar to those used for fish and shrimp farming; and closed systems, carried out in sheltered places and under strict control of environmental conditions.

Open and semi-closed systems represent a more traditional form of cultivation and still widely used to produce *C. sapidus* crabs in the United States (Oesterling 1988; Kennedy & Cronin 2007) and *S. serrata* and *P. pelagicus* in Asian countries (Dat 1999; Trino *et al.* 2001; Mwaluma 2002; Shelley 2008; Primavera *et al.* 2010; Paterson & Mann 2011; Shelley & Lovatelli 2011). However, in recent years, industrial scale swimming crab production has focused on closed production systems (Kennedy & Cronin 2007; Gaudé & Anderson 2011).

Open systems

The open systems used still hold some of the characteristics of the production systems used in the 1850s (Rathbun 1887; Roberts 1905), especially when fences are used to enclose the crabs (Oesterling 1993). This system is placed in coastal areas, such as bays, coves or lakes in shallow waters. The structures are buried in places deep enough to keep them partially submerged, even during the low tide (Oesterling 1988).

Enclosure farming represents the most primitive and least technical method to obtain soft-shell swimming crabs, among systems currently used. According to Oesterling and Moore (1995) and Kennedy and Cronin (2007), these traditional systems suffer from important technical limitations and inefficiencies. In addition to being heavily influenced by natural temperature fluctuations and environmental salinity, and high rates of cannibalism, their main problem is the intrinsic difficulty to identify the exact moment of the occurrence of ecdysis, preventing a fast and efficient harvesting.

Initially, the enclosures used in the production of crabs were circular shaped and constructed with vertically arranged stakes or thin plates of wood and nailed together to prevent the crabs from escaping (Roberts 1905; Kennedy & Cronin 2007).

A more recent development of this traditional enclosure system has been the installation of individual floating boxes or cages to protect the swimming crabs from cannibalism and predator action (Fielder *et al.* 1988; Oesterling & Moore 1995; Kennedy & Cronin 2007; Shelley & Lovatelli 2011). For this purpose, the enclosures suffered changes in their basic design (Fig. 1). The wooden stakes were arranged in a more distally manner, in a quadrangular shape to improve the internal distribution and to protect the floating cages from the action of the wind and waves (Kennedy & Cronin 2007).

Floating cages can be made entirely of wood or polyethylene. They usually measure between 7 and 10 cm wide, 30 cm long and 38–45 cm deep (Oesterling & Moore 1995).

Comparatively, floating cages are the cost-wise cheapest system in terms of construction, maintenance and operation, among the systems used in the production of crabs (Oesterling 1988; Oesterling & Moore 1995; Gaudé & Anderson 2011). Nevertheless, the disadvantages may outweigh the advantages (Oesterling 1988; Oesterling & Moore 1995).

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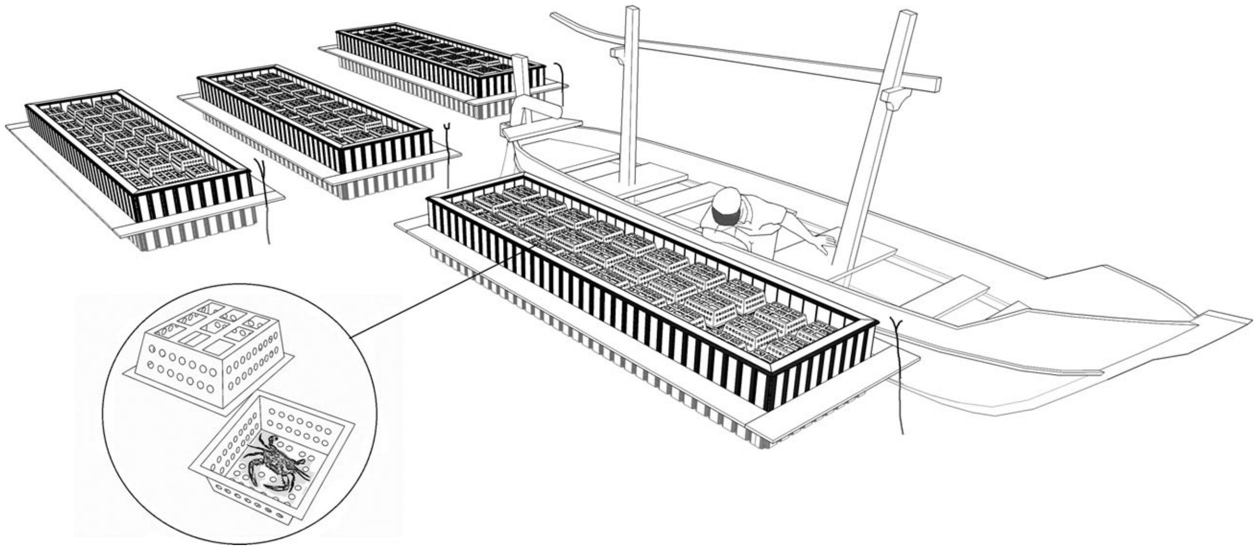

Figure 1 Illustration of the open system for soft-shell swimming crab farming, representing the routine work of the identification of ecdysis occurrence. The cage where the crabs are kept is shown in detail.

Production on an industrial scale requires the installation of thousands of floating cages, which end up occupying a large area (Oesterling 1988). The difficulty of access to be the greatest disadvantage, as the management requires the use of boats, generally involving labour discomfort associated with the handling of the cages, as operators must work in a curved position under the edge of the boat to access the cages (Gaudé & Anderson 2011).

In places where open systems are still used, the production of soft-shell swimming crabs often shares space with the cultivation of other species of commercial interest (polyculture) (Milstein 2005). This model is common in Malaysia and Thailand, where *S. serrata* can be produced together with tilapia (*Oreochromis niloticus*), milkfish (*Chanos chanos*), and mullet (*Mugil mugil*), as well as other crustaceans such as shrimps (*Penaeus indicus* and *Penaeus monodon*) (Mwaluma 2002) and even macroalgae, namely *Gracilaria* sp. (Chen 1990).

Semi-closed systems

Few changes occurred in the production systems until 1950, when a new system was developed. The floating cages were placed inside aquaculture ponds built on land, filled with water pumped from an adjacent brackish or salt water source and returned to the environment after use (Oesterling 1988; Trino *et al.* 2001). (Oesterling & Moore 1995).

The ponds currently used are rectangular, with an average area of 100–200 m^2, with the bottom covered with a layer of mud or sand and mud (Fig. 2) (Keenan & Blackshaw 1997). The crabs are not cultivated loose in the nursery as in shrimp farms. Thus, the animals are kept in small individual cages supported on floating systems, similar to those used in open systems (Oesterling 1988; FAO, 2015). The cages are installed in long and narrow floating structures arranged side by side. To ease the management of the cages and the identification of moult, a walkway structure similar to a bridge, usually built of wood, is installed.

The semi-closed system was designed with the purpose of improving and easing the management in the production of soft-shell swimming crabs, with respect to the management problems described for open systems (Kennedy & Cronin 2007). In many cases, the ponds may be filled up to waist level to provide a better postural position for workers during routine activities (Oesterling & Moore 1995).

In addition, this system offers greater protection from weather and from some predators, and the possibility of some control, although limited, of the quality of the water, mainly of the salinity (Kennedy & Cronin 2007).

However, despite advances in water quality control, the system still depends on the existence of salty/brackish water in conditions close to ideal. Moreover, compared with the systems described above, the nurseries involve higher construction and operational activity costs.

Moreover, compared to the more primitive systems described above, the nurseries involve higher construction and operational costs (Kennedy & Cronin 2007).

The enterprises Seafood Company (2016), located in Makassar, Indonesia, and Aung Moe Khine Manufacturing (2016), located in Myanmar, are examples of soft-shell swimming crab-producing farms using floating cages.

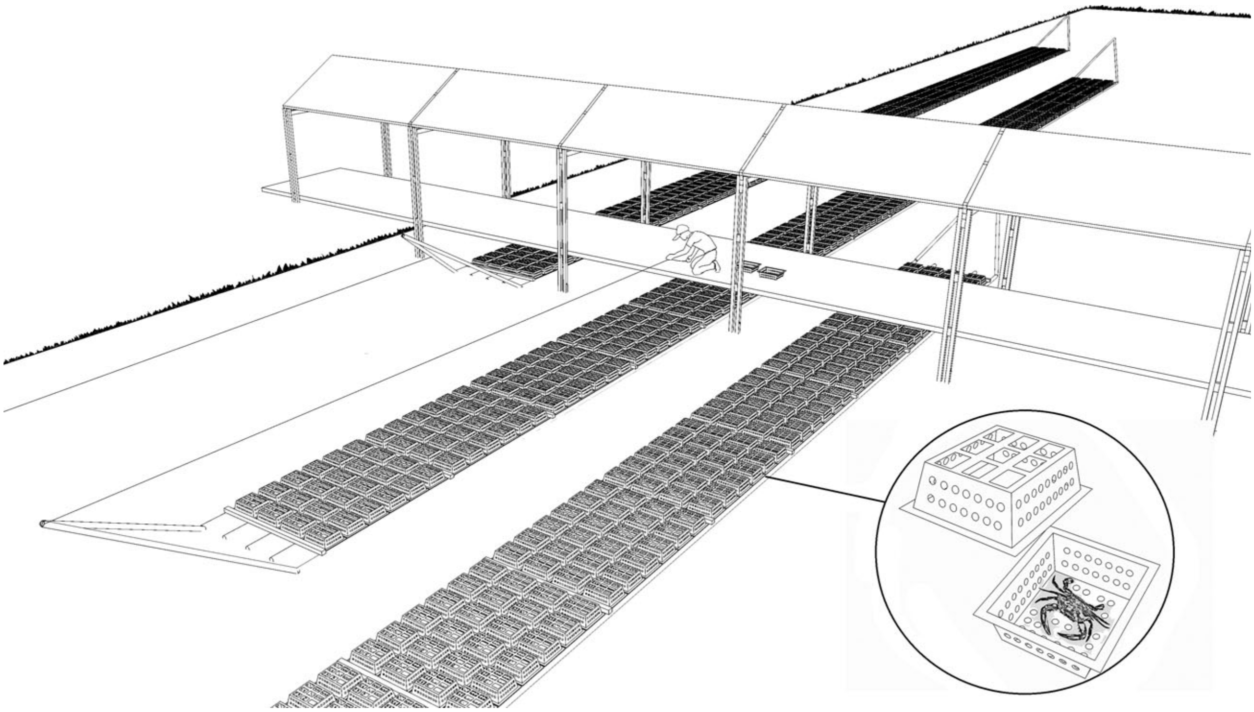

Figure 2 Illustration of the semi-closed system of the production of soft-shell swimming crabs, representing the routine work of the identification of ecdysis occurrence. The cage where the animals are kept is shown in detail.

Currently, the companies produce, respectively, 30 and 50 tons of *Scylla* crabs monthly.

Closed systems

The closed system represents the most modern form of soft-shell crab production. The main characteristic is the use of recirculation systems, where water flows through the animal maintenance structures and then through filtration equipment or structures (mechanical, biological and chemical) before returning to the production system (Ogle *et al.* 1982; Perry *et al.* 1982; Malone & Burden 1988).

The maintenance structures use in close systems can be communal or individual (cell compartments). Several types of tanks built of wood, concrete, polyethylene or fibreglass can be used as communal structure (Oesterling 1988). Cell structures, in turn, involve water circulation through overlapping boxes, cages or drawers (Fig. 3) (Shelley & Lovatelli 2011).

This type of production system offers several advantages over the traditional methods above mentioned, such as ensuring a greater control over environmental and operational variables; significantly increasing the availability of locations for the installation of production units; allowing the adoption of high stocking densities; and enabling a better monitoring of the occurrence of ecdysis, aside from allowing several forms of automation (Malone & Burden 1988; Gaudé & Anderson 2011; Shelley & Lovatelli 2011).

As it could be expected, closed systems are more complex, requiring more skilled labour and greater investment and production costs (Oesterling 1988). There are currently on the market several equipments for recirculating water indoors, including some complete cell systems specific for the production of soft-shell swimming crabs. A system with capacity for 100 animals can be purchased, directly from specialized online sites, priced between US$ 10 000 and 15 000 (Zhongkehai, 2016).

Comparisons between productive systems

From the operational point of view, the conditions and benefits of semi-closed systems appear in intermediate position between the extremes (open and closed systems). Open systems are simpler and cheaper, but they allow less control of the operational variables associated with the soft-shell crab production. In closed systems, these same variables are better controlled, but at the expense of larger financial investments (Table 1). Even as today, the different systems used for soft-shell crab production continue to coexist by allowing access to the means of production to different publics, which, in turn, adapt to the different human, material, environmental and financial resources available.

The literature is somewhat scarce in terms of commercial information, which makes quantitative comparisons between

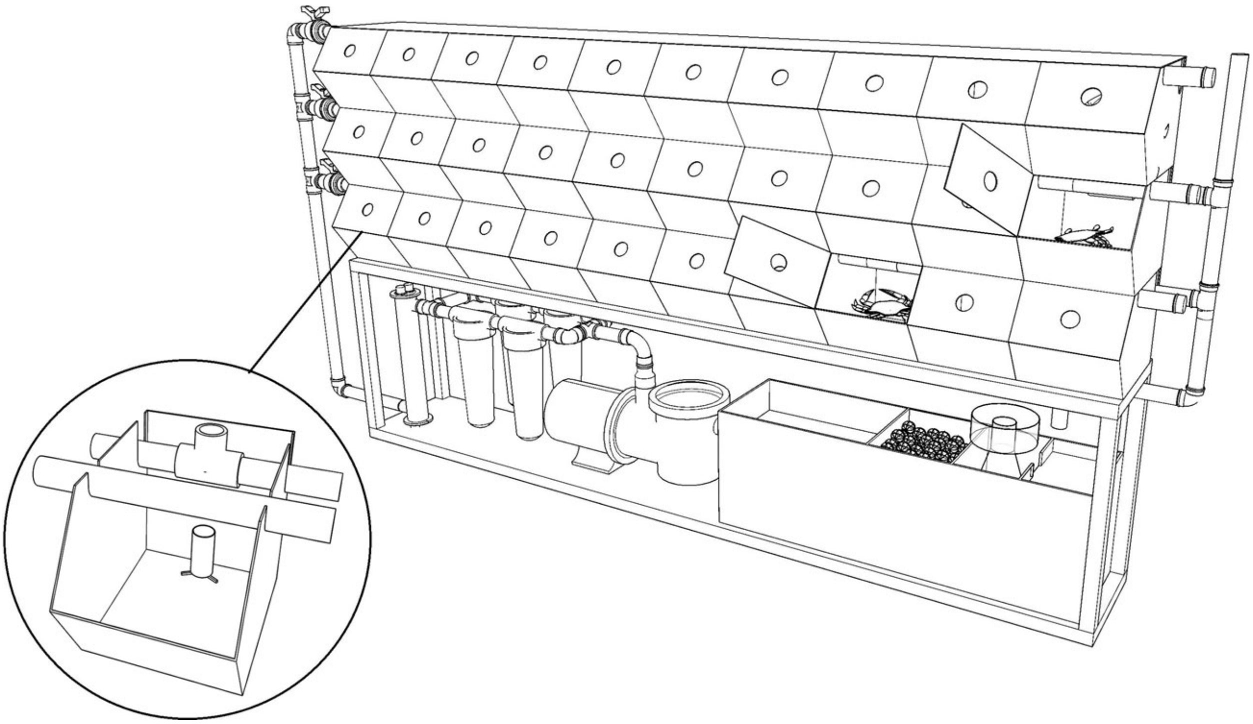

Figure 3 Illustration of the closed system of cell compartment type for the cultivation of soft-shell swimming crabs. The compartment where the crabs are kept is shown in detail.

open and closed systems a difficult task. This scarcity is explained in most part by lack of interest to collect or publish data. For one side, the small-scale or family operated business usually does not perceive the advantages of keeping records of this type of data. For other side, larger firms in general have no interest to disclose information on their production data. Data regarding zootechnical information, although also rare, can be obtained from controlled experimentation works and generally address only to final survival rates. Different authors, working in closed, semi-closed and open systems, and utilizing different species of crab, obtained results that can be comparable.

Chaves and Eggleston (2003) compared the survivor rates of adult *C. sapidus*, maintained in closed recirculation system until moulting, with individuals maintained for the same periods of time in tanks with daily water exchange, simulating an open system. As the individuals were usually captured already in premoult, the maintenance time was usually short. As a result, the author did not observe significant differences between registered survival rates ($P > 0.05$). Zmora *et al.* (2005) compared survival rates of juveniles of *C. sapidus*, cultivated in a closed system, to those obtained in tanks with daily water exchange. As this experiment was conducted in longer periods of time, the authors observed slightly higher survivorship in the closed system as compared to de open system (42.9% and 39.4%, respectively). More recently, Bowers *et al.* (2011), also working with *C. sapidus* obtained a significantly higher survival rate in the recirculation system (86%) in comparison with the open system (68%).

Mirera and Moksnes (2015), working with juveniles of *S. serrata*, compared results of cultivation in semi-closed system, composed by cages positioned in a aquaculture pond, with the open system that of fenced areas in coastal lagoon. The authors obtained significantly higher survival rate (59%) in former, when compared to latter (40%). Comparing technical results described in different experiments with juveniles of *S. serrata* cultivated in open systems (Genodepa 1999; Mwaluma 2002; Mirera 2009; Primavera *et al.* 2010) with those obtained in semi-closed system (Triño *et al.* 1999; Trino *et al.* 2001), we also obtained similar results as Mirera and Moksnes (2015).

In addition to the operational advantages of the closed system, recent studies have reported the occurrence of acute mortality in companies producing soft crab caused by a crab-specific reovirus (CsRV1) (Bowers *et al.* 2010; Flowers *et al.* 2016) and that the pathogenicity of this virus is related to high temperatures (Chung *et al.* 2015). These findings would reinforce an additional advantage of closed production systems over open systems, due to greater possibility of control of environmental variables, including temperature, in this kind of system.

Table 1 Comparative analysis of the main characteristics of different systems used worldwide in the production of soft-shell swimming crabs

Factors analysed	Open systems		Semi-closed systems	Closed systems	
	Communal fence	Fence with cell compartment (floating cages)	Pond with cell compartment (floating cages)	Communal tank	Cell compartment
Operational and investment costs	○	○	●	●	●
Monitoring the occurrence of moult	○	○	◍	●	●
Ease of harvest	○	○	◍	●	●
Ease of handling	○	○	◍	●	●
Water quality control	○	○	◍	●	●
Control of cannibalism	○	●	●	○	●
Predator control	○	◍	◍	●	●
Access to the production system	○	○	◍	●	●
Automation of the productive process	○	○	○	◍	●

●, high; ◍, medium; ○, low.

Production techniques

Obtaining individuals

The animals used in the production of soft-shell swimming crabs are mainly obtained through the capture of individuals in the premoult stage in the natural environment and then kept in captivity until moulting. Several methods are commonly used to capture animals in the wild, such as traps, purse seines and even manual collection (Oesterling & Moore 1995; Guillory & Prejean 1997; Songrak *et al.* 2013; Anderson & Alford 2014).

Each of these methods is usually adapted to specific geographic, environmental and legal regimes, as determined by local regulatory agencies, respecting specific size limits and the times of the year in which captures are authorized (Gaudé & Anderson 2011).

However, methods of obtaining swimming crabs are directly dependent on natural stocks which, in turn, are vulnerable to pressure from overfishing, pollution or climate changes. Different combinations of these factors have been responsible for the decline of populations in recent years in many regions of the globe (Lindner 2005; Paolisso 2007; Shelley 2008; Zohar *et al.* 2008; Johnston *et al.* 2011; Shelley & Lovatelli 2011; Ikhwanuddin *et al.* 2012).

The decrease in the fishing supply of swimming crabs has motivated the research aiming the development of breeding techniques, larviculture and fattening of crabs, under controlled environmental conditions in recent years (Zohar *et al.* 2008).

A relatively well-controlled technology for the reproduction, larviculture and fattening, under controlled environmental conditions, is already available for the mud crab, *Scylla* spp. (Keenan & Blackshaw 1997; Shelley & Lovatelli 2011), the blue crab, *C. sapidus* (Zmora *et al.* 2005) and the blue swimmer crab from the South-East Asia region, *P. pelagicus* (Azra & Ikhwanuddin 2015).

Despite this, the full cycle of crabs production, exclusively from aquaculture, is still an incipient activity worldwide (Zohar *et al.* 2008; Igarashi 2009; Paterson & Mann 2011; Azra & Ikhwanuddin 2015).

Some of the main difficulties to accomplish the full closure of Portunidae cultivation cycle are the mass mortality events during larviculture trials (Azra & Ikhwanuddin 2015) which are probably caused by technical inadequacy of farming systems (Paterson & Mann 2011); high rates of cannibalism due to high storage densities (Mann *et al.* 2007; Azra & Ikhwanuddin 2015); and the need for better matching of nutritional requirements for cultivation species and stages (Keenan & Blackshaw 1997; Geoff & Fielder 2004; Paterson & Mann 2011; Azra & Ikhwanuddin 2015).

Routine management

During the captivity period, crabs can be fed with a wide variety of food items, including pieces of fresh fish, mussels, shrimp fragments, small bivalves, animal skins and entrails, and even formulated shrimp feeds (Shelley & Lovatelli 2011). Food is usually offered every 2 or 3 days at a ratio of approximately 2–8% of the total biomass of stored crabs or until satiety (Keenan & Blackshaw 1997; Kennedy & Cronin 2007; Paterson & Mann 2011; FAO, 2015).

In collective farming systems, feeding is also used as a strategy to minimize cannibalism, which is more frequent when crabs are famished. When the crabs are grown or kept in individual systems, it is possible to keep the animals in a fasted premoult stage without affecting the efficiency of the production process (Shelley & Lovatelli 2011).

A continuous monitoring of the most important physical and chemical parameters (temperature, salinity, dissolved oxygen and ammonia) determining the water quality in the production systems should be performed, especially in closed systems (Lakshmi 1984; Malone & Burden 1988; Gaudé & Anderson 2011; Liao *et al.* 2011). Hochheimer (1988) and Malone and Burden (1988) recommend water quality parameters in the culture of soft-shell swimming crabs in recirculation systems to be kept within the limits indicated in Table 2.

Low concentrations of dissolved oxygen are considered one of the major causes of mortality of cultivated swimming crabs in captivity (Vega-Villasante *et al.* 2006), because during ecdysis, swimming crabs have difficulty adjusting their breathing in environments with oxygen concentrations below 6.0 mg L^{-1} (Hochheimer 1988). This occurs because throughout ecdysis structures related to the respiratory process are eliminated along with the exoskeleton, or are too soft to efficiently fulfil their role (de Fur *et al.* 1985).

Identification of ecdysis occurrence and harvesting

The final part of the productive process, the most complex and laborious of all, is the identification of the occurrence of ecdysis and the immediate harvesting of individuals. The calcification process begins immediately after the loss of old exoskeleton and in less than 1 h the new skin may already present a leathery texture (Wheatly 1999). After 3 hours, the exoskeleton has a firm consistency and may be described as having a papery texture, point from where it loses its commercial value as 'soft crab' (Freeman *et al.* 1987). Animal at premoult stage should be closely monitored to ensure that they are removed from the water before calcification and hardening of the new exoskeleton begins (Oesterling 1988; Perry *et al.* 2001; Ferdoushi *et al.* 2010).

As swimming crabs usually display several morphological signs of the approach of ecdysis, the premoult period can be identified by visual inspection (Drach 1939; Freeman *et al.* 1987; Oesterling & Moore 1995). The most reliable and widely used method involves the observation of the last pair of pleopods. During the premoult period, the new exoskeleton begins to form becoming visible beneath the old exoskeleton (Kennedy & Cronin 2007). At the beginning of the premoult stage, it is possible to observe a white line along the distal edges of the pleopods, mostly in the second segment of the pleopods (Fig. 4).

Table 2 Water quality recommendations for soft-shell swimming crab cultivation in a closed system

Parameter	Recommended limit
Dissolved oxygen	Above 7.0 mg O_2 L^{-1}
Ammonia	Below 0.5 mg NH_3 + NH_4–N L^{-1}
Nitrite	Below 0.5 mg NO_2–N L^{-1}
Temperature	Between 22 and 28°C
Salinity	5 ppm above/below of harvesting water
pH	Between 6.5 and 8.5
Alkalinity	Above 100 mg L^{-1} $CaCO_3$

As ecdysis approaches, this line gradually changes colour assuming a pinkish colour, indicating that ecdysis will occur in about a week. Next, the line becomes reddish, indicating that ecdysis should occur within 1 or 2 days (Kennedy & Cronin 2007).

The success of soft-shell swimming crab production requires workers sufficiently trained to identify animals going through premoult and ecdysis, both at the time of capture and later during the cultivation stage (Shelley & Lovatelli 2011). The work is particularly arduous, considering that a production unit (in the case of individualized systems) can house between 10 000 and 50 000 individual boxes, requiring inspection more often than once a day (Keenan & Blackshaw 1997).

Failing to timely harvest the animals significantly diminishes it is market value and, in a long run, may compromise the success of the operation (Ferdoushi *et al.* 2010). In the face of this challenge, some attempts to automate this process have been developed.

Malone and Culley (1988) developed a method for the automatic separation and harvest of the recently moulted swimming crabs, using the water flow as a tool in the process. The system includes a tank with a water inlet and an outlet channel on the other end, filled with enough water to cover the crabs. The system is configured and dimensioned so that the water flow is strong enough to move the newly changed crabs to the outlet channel, as the soft-shell crabs lose their locomotion control, but it is insufficient to displace the hard crabs. Despite the simplicity of this concept, its use and efficiency in the commercial production of soft-shell swimming crabs are unknown, due to the lack of data records in producing countries.

More recently, the Australian company Watermark Seafoods has invested in high technology to optimize the production process, developing the most sophisticated water recirculation system currently used in the production of soft-shell swimming crabs (Shelley & Lovatelli 2011). The equipment virtually eliminates the need for human inspection, replacing it with a robotic identification system of animals suitable for consumption (Blanch 2012; Tobias-Quinitio *et al.* 2015).

According to the inventor of this system, Angus Cameron, during an interview given to Blanch (2012), the equipment has the ability to monitor up to 40 000

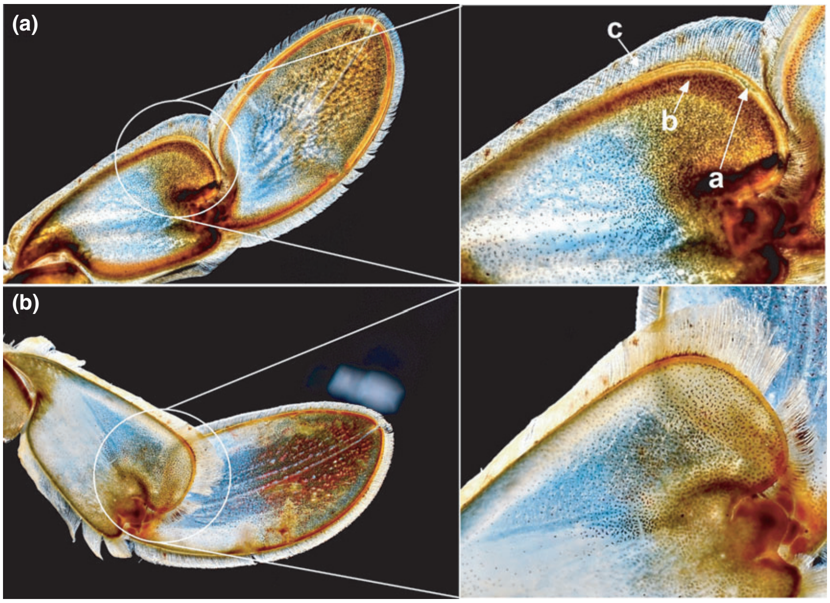

Figure 4 Presence of the macroscopic signal of ecdysis in the pleopod of a crab in the premoult stage (a) and absence in a crab in intermoult (b); detail 'a' indicates the white line along the distal edges of the second segment of the pleopod; detail 'b' shows the reddish colour indicative of the proximity of ecdysis, which is the bristles of the new epicuticle folded along the edges (b); and in 'c', the bristles of the old epicuticle.

swimming crabs kept in individual compartments in a closed system. This robotic mechanism is designed to monitor the stage of ecdysis of each animal within 2 h, operating as follows: first, the robot determines, through the capture of images performed through an automated camera, whether or not there is an animal in the individual compartment. The equipment then introduces pieces of fish into the compartments where the presence of animals has been confirmed. Based on the acceptance or not of the food, the robot registers the information in the system, as ecdysis is expected to occur within 3 days. When ecdysis occurs, the robot is able to identify, through the image capture system and specific software, the presence of two bodies in a certain compartment (the body of the crab and its exuviae). The robot then removes the animal from the system and makes it available for processing. The detailed patent description is available in Campbell *et al.* (2006).

Slaughter

Regardless of the system used, soon after ecdysis, the crabs are removed from the production structures, placed under refrigeration and then sent to the processing plant. It is important that crabs arrive with the intact exoskeleton and alive for processing; otherwise, they must be discarded (Kennedy & Cronin 2007; Gaudé & Anderson 2011; Shelley & Lovatelli 2011).

The animals are individually packaged while still alive. They are slaughtered by rapid freezing at −28°C to ensure a quick culling and to provide a high product quality. After freezing, the crustaceans can be stored at −15°C, a sufficient condition to preserve the product up to 1 year without significant loss of quality (Lawlor *et al.* 1997; Shelley & Lovatelli 2011).

Conclusion

The rising real estate prices in coastal areas, the search for greater efficiency in the production process, the development of new automation technologies and the strong increase in demand associated with the valorization of the product in the market are factors that have created conditions for the development of closed systems of the production of soft-shell swimming crabs worldwide. This activity has the potential to occupy a prominent place in the aquaculture industry worldwide in the coming years. However, full supply of production by harvesting systems, completely independent from the capture in natural environments, is still far to come, which reinforces the need for investment and research on problems such as reproduction and larviculture, food and nutrition, and captive swimming crab management techniques.

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