Chapter

Management of the Interaction and Cannibalism of Postlarvae and Adults of the Freshwater Shrimp *Cryphiops caementarius* (Molina, 1782)

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Abstract

Cryphiops caementarius shrimp inhabits the rivers of the western slope of the Andes of Peru and Chile. But the greatest population densities found in the rivers of Arequipa (Peru) have social, economic, commercial, and gastronomic importance. Researches on this species of shrimp date from 1950. The males of *C. caementarius* are aggressive by having one of the most developed chelipeds, causing greater interaction and cannibalism. To reduce the interaction of the species, it has been used two culture systems. For postlarvae, using brackish water can maintain high survival (>85%), but only in initial culture which lasts for 50 days. For the fattening of adult males, culturing in separate containers conditioned in various levels improves the survival (87–100%) and yield (1.0 kg m^{-2}), and with this system, the culture is also performed with tilapia. It is still required to demonstrate the technical and economic feasibility of fattening male shrimp in individual containers within seminatural ponds.

Keywords: freshwater shrimp, cannibalism, interaction, culture systems

1. Introduction

The Palaemonid shrimps that inhabit the rivers of the western slope of the Andes are represented by 12 species, three of which correspond to the genus *Palaemon*, eight to *Macrobrachium,* and one to *Cryphiops* [1]. Of these, *Cryphiops caementarius* (Molina, 1782) inhabits the rivers of the coast of Peru and Chile. However, only in Peru, it has social, economic, and commercial importance since it is extracted from the Pativilca River in Lima to the Tambo River in Arequipa, where there is high population density [2], which, in 2016, was captured as 1112.9 t [3]. In addition, the species has culinary importance whose potential markets are restaurants in the regions of Lima and Arequipa in Peru [4]. *C. caementarius* is also distributed until Valparaiso in Chile [5], although with less commercial importance due to the low population densities and because it is a vulnerable species in the northern region and in danger of extinction in the Metropolitan Region of Chile [6].

Other species of *Cryphiops* inhabit caves in the state of Chiapas in Mexico, as *C.* (*Bithynops*) *luscus* and *C.* (*Bithynops*) *perspicax* [7] and *C. (Bithynops) villalobosi* inhabits rivers and streams [8]. In Brazil, *C. brasiliensis* inhabit in a river of the Federal District [9]. All these species are small in size, whose populations are not attractive to trade.

Researches related to shrimp *C. caementarius* date from 1950, and the generated interest is in order to establish commercial cultivation. However, the culturing is affected as the strong interaction given the size and thicker of the second pair of pereiopods that is a sign that the species is aggressive, and for the cannibalism that happens between congeners. These limitations affect the growth and yield of shrimp.

The purpose of this chapter was to review progress in research with that of the freshwater shrimp *C. caementarius*, related to alternative solutions to the problems of the management of the interaction and cannibalism of postlarvae and adults.

2. Interaction

In decapod crustaceans, there are those who are very aggressive as portunids crabs (*Scylla*, *Callinectes*, and *Portunus*), king crabs (*Lithodes* and *paralithodes*), followed by chelated lobsters (*Homarus* and *Nephrops*) and spiny lobsters (*Panulirus* and *Jasus*), and also, those who are less aggressive as crayfish (*Procambarus*, *Cherax*, *Pacifastacus*, and *Astacus*) and penaeids (*Litopenaeus*) and are less cannibals [10]. Therefore, the aggressiveness between congeners depends on the species.

In the territorialist decapod crustaceans, the second pair of pereopods (chelipeds) is long and thick and also those are used for attack and defense, for agonistic interaction and for courtship and mating [11]. Males of *C. caementarius* have one of the most developed chelipeds (**Figure 1**), either the right or the left. In females, the chelipeds are of similar size. This morphological feature of the chelipeds makes males an aggressive species whose interaction and cannibalism are observed in aquariums, tanks, and ponds [12], but this behavior has not been assessed yet. In *Callinectes arcuatus* and *C. bellicosus*, the chelipeds are dimorphic, and generally, the right cheliped is the largest and the thicker that permit to consume mollusks and crustaceans [13].

The interaction of male *C. caementarius* is greater than that of females, because of this situation, males always show serious injuries in the cephalothorax, abdomen, and chelipeds, although it is common to observe shrimps without chelipeds. In juvenile *C. caementarius*, interaction and increasing stocking density cause high metabolic rate (87–91%) that affects the growth in weight [14] and probably the physiological state of the animal. In *Macrobrachium rosenbergii*, the chelipeds of older males are larger and thicker with which they access easily to food and shelter, in addition to giving them greater ability to combat due to the visualization of the

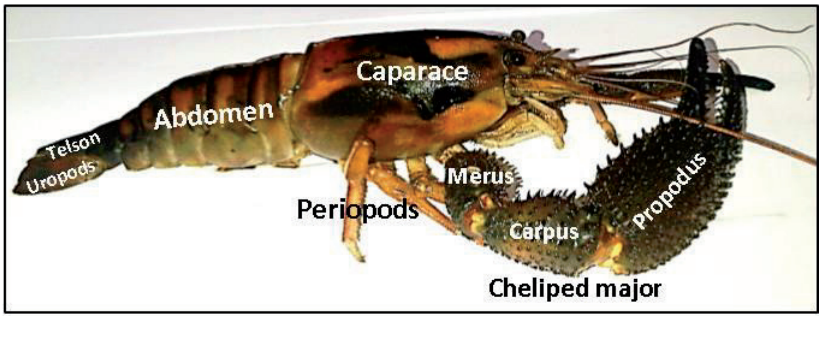

Figure 1.
Body parts and appendages of the freshwater shrimp C. caementarius.

opponent [15, 16]. This explains why the most affected parts of the crustaceans are the pereopods, pleopods, antennae, antennules, and uropods [17].

3. Cannibalism

All decapod crustaceans use chelipeds for interaction, access to food, shelter, and mating, resulting in energy expenditure during the fight and can reach the autotomy of appendages and even cannibalism. Cannibalism, defined as intraspecific predation, is a behavior established in a wide variety of animals [18] and is considered as the process of killing and eating an individual of the same species [19], whether it consumes all or part of it. In *C. caementarius*, cannibalism is often a response to captivity, lack of shelter, ecdysis, increased density, lack of food, and poor water quality, and it is probably a natural behavior.

The molting fluid accumulated between the old cuticle and epidermis is the product of degradation of the old cuticle [20], which is released with ecdysis and acts as a chemical stimulant [21]. In the Hermit crabs, *Clibanarius digueti* and *Paguristes perrieri*, the odor of the injured animals of the same species as well as other species is a feeding signal [22]. Similarly, the odor released during autotomy to escape a predatory aggression influences agonistic behavior in decapod crustaceans [10]. The *C. caementarius* adults who are close to the ecdysis (premuda D3 and D4) during ecdysis (E) or after ecdysis (postmoult A) are more prone to cannibalism, mainly after the ecdysis, where the soft exoskeleton, which takes time to harden, makes movement and defense difficult for himself. The cannibalism of C. caementarius starts from Zoea 8 and increases as they grow [23, 24]. These observations indicate that cannibalism may have a genetic component, at least in the species, as suggested in other cannibalistic species [19].

In *M. rosenbergii*, interaction and cannibalism by molt is attenuated with the use of shelters [25, 26], artificial substrates [27, 28], and by increasing tryptophan in the diet [29], with which high survival is maintained and growth is improved. Further research is needed to evaluate these culturing systems in *C. caementarius*.

4. Cultivation of postlarvae in brackish water

The crustacean's cultivation comprises producing postlarvae in hatchery, the postlarvae growth until reaching juvenile stage or condition of preadult and the fattening until reaching commercial weight (>20 g). Postlarvae adapt to environmental conditions during the initial culture, and those who survive are resistant, and have higher growth rate. However, as mentioned, the problem is the interaction and cannibalism that happens throughout the animal's life. Similar advantages are reported during the nursery phase of *M. rosenbergii* postlarvae due to the interaction and cannibalism [30].

To reduce cannibalism of postlarvae during communal cultivation and obtain juveniles with greater weight (200 mg) for stocking in ponds, growing in brackish water should be performed. Recent postlarvae of *C. caementarius* (11 mm total length and 40 mg total weight) have remarkable euryhalinity and achieve greater weight when grown for 50 days in brackish water of 12‰ and with density of 114 PLs m^{-2} [31]. These results demonstrate the physiological efficiency of organisms to accumulate biomass in such salinity conditions, probably because they are in their isosmotic point. In addition, 95% of postlarvae survive in water with salinity of 12‰, 70% live in water of 24‰, and 40% in fresh water. This high survival of postlarvae in brackish water than in fresh water is due to the reduction of cannibalism probably because the released substances before, during, and after ecdysis are attenuated by ions of the brackish water from the culture medium [31].

Furthermore, the culture of postlarvae *C. caementarius* in brackish water with 12‰ allows increasing the density up to 500 PLs m^{-2} without affecting the growth and survival after 60 days of culture [32]. In juveniles of *M. tenellum* [33] and *M. rosenbergii*, the higher growth and higher survival (>90%) are obtained in water with 10‰ salinity [34]. Under these conditions of salinity and density, it is convenient to use shelters or artificial substrates to enhance the growth of postlarvae.

5. Adult shrimp culturing in individual containers

The main problems of the communal culturing of adult crustaceans are the interaction and cannibalism per molt, which are accentuated as the animals grow and affect the growth and survival, respectively. In the communal culturing of *C. caementarius*, survival decreases to 17% in aquariums [12] and 25% in tanks [24, 35]. In seminatural ponds, it is likely to obtain survivals between 40 and 50%, and even the density is 5 shrimp m^{-2}, due to increased cannibalism. These survival results of the species prevent the establishment of commercial cultivation.

Cultivation in individual containers was first used in lobster *H. americanus* where the container shape (circular, square, and rectangular) does not affect the growth, but the size of these (20–181 cm^2) retards the growth [36]. Larger containers were also used (750 cm^2) [37]. The cultures in individual containers and conditioned at several levels used are *Cherax tenuimanus* [38], *C. quadricarinatus* [39], and *H. americanus* [40, 41]. Although the circular containers can have mesh as used in *H. gammarus* [42]. In any type of culture container, physical interaction of organisms is avoided, improving the growth and survival.

The first cultivation system in individual containers was performed with adult females *C. caementarius* [43] and then with males [12], both in aquariums (**Figure 2**) and fiberglass tanks (**Figure 3**). In this system, the species tolerates cultivation in containers of reduced physical space (133–284 cm^2), not being affected by ovarian maturation, the spawning, the molting period, and the growth and survival during 4–6 months of culture. Moreover, the lower specific density factor k = 16 means that the species requires less space than the other crustaceans [12] obtained. The specific density factor is an indicator when the size of the containers inhibits the species growth, and the k factor is ≤ 22 from *C. quadricarinatus* [39], k ≤ 45 from *C. tenuimanus* [38], and k ≤ 50 from *C. destructor* [44]. That is, these species of crustaceans cannot tolerate reduced physical spaces during cultivation in individual containers.

Figure 2.
System culture of C. caementarius in individual containers conditioned in aquariums with water recirculation system and biofilter.

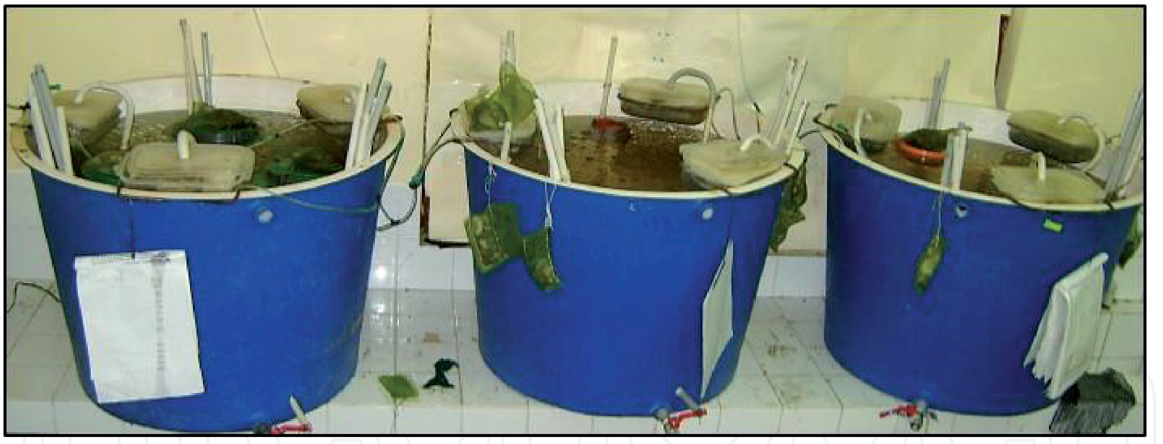

Figure 3.
System culture of C. caementarius in individual containers conditioned in fiberglass tanks with water recirculation system and biofilter.

Individual containers are conditioned in various levels, both aquariums and tanks or seminatural ponds, thus increasing the planting density. In aquariums (0.186 m^2 and effective volume of 55 L), the containers are installed in three levels, but in two columns, making a total of six containers per aquarium equivalent to 32 shrimps m^{-2} (**Figure 2**). In fiberglass tanks (with a bottom area of 0.159 m^2 and an effective volume of 100 L), the containers are installed in five levels, but in three columns, making a total of 15 containers per tank equivalent to 94 shrimps m^{-2} (**Figure 3**). In both cases, the increased production is achieved in large containers (284 cm^2), although no significant differences with those of smaller areas (**Table 1**) are seen. In *C. quadricarinatus*, the culture containers are conditioned in seven levels within 3 m^2 tanks where high yield in containers of 490 cm^2 is achieved [39]. But, as shrimp *C. caementarius* is sold by weight, including the chelipeds, then it is preferable to use the large containers. Shrimp farming in individual containers installed in seminatural ponds has not been investigated, but environmental and productivity pond water conditions could benefit the growth, color of the shrimp, and reduce the feed conversion.

The effective density is the number of surviving organisms at the end of the culture period according to the area of the container. In *C. caementarius*, the effective density of 94 shrimps m^{-2}, obtained by cultivation in individual containers, is considered high, and therefore, cultivation is intensive, which could produce 10.5 t ha^{-1} per period in 4 months (**Table 1**), and get 31.5 t ha^{-1} y^{-1}, which is 10 times higher than that one obtained in semi-intensive monoculture of *M. rosenbergii* reaching 3 t ha^{-1} y^{-1} [45]. However, in *C. quadricarinatus*, stocked in individual containers, the final effective density after 100 days of culture was between 143 and 348

Container		Effective density (shrimp m^{-2})	Final weight (g)	Estimated performance (kg m^{-2})	Estimated production* (t ha^{-1} $period^{-1}$)
Area (cm^2)	Diameter (cm)				
133	13	94.34 ± 0.00	8.09 ± 1.37^a	0.763 ± 0.129^a	7.64 ± 1.29^a
201	16	94.34 ± 0.00	9.99 ± 0.62^{ab}	0.941 ± 0.058^a	9.42 ± 0.59^a
284	19	81.76 ± 10.89	13.20 ± 1.99^b	1.049 ± 0.059^a	10.49 ± 0.59^a

Data were estimated for a 4-month period. Letters a and b in superscript in a column indicate that there is a significant difference ($p < 0.05$).

Table 1.
Estimated production (mean ± standard deviation) of males of C. caementarius cultivated during 4 months in individual containers of different sizes conditioned in five levels inside fiberglass tanks [12].

individuals m^{-2} and the yield between 4 and 8 kg m^{-2} [39]. Future research should establish in detail the conditions of the cultivation system in individual containers, to intensify the cultivation of *C. caementarius*. Parallel to this, a technical-economic study must be made to know the feasibility of shrimp farming in the system.

However, the cultivation of *C. caementarius* in individual containers causes loss of body color and of cephalothoracic appendages (**Figure 4**), but the use of *Capsicum annuum* (250 mg kg^{-1}) [12] and in the diet (300 mg kg^{-1}) improves pigmentation of the body [46]. Consequently, the shrimp diet should contain carotenoid pigments, since crustaceans cannot synthesize carotenoids de novo [47]. Body depigmentation attributed to diet happens in *C. tenuimanus* [38] and *H. gammarus* [40], when they are grown in individual containers.

In the culture of *C. caementarius* in individual containers, the management of food at the commercial level would imply a cost of additional labor that increases the cost of cultivation. It is, therefore, necessary to design a food distribution system as used in *Homarus* sp. [48] and *H. gammarus* [49]. In species of *Scylla*, the most sophisticated designed system to date includes cameras linked to a computer system that regularly scans the cells to see if there are one or two crabs in each container indicating that the crab has made an ecdysis, by the presence of exoskeleton and crab. In addition, this system also includes a sophisticated water recirculation system [50].

In studies with male shrimps *C. caementarius* in individual containers installed in aquaria and tanks with recirculation system with water and biological filters, growth is evaluated by eyestalk ablation [51] per culturing at different water hardness [52] and by different inputs used in the diet such as paprika [46], yeast [53], common salt [54], biological silage [55], and soya lecithin [56]. Survival of >90% are obtained in all these investigations, which demonstrates the effectiveness of the culture system by avoiding the physical interaction and cannibalism of river shrimp. In similar culture conditions, survivals between 71 and 83% in *C. tenuimanus* [38] and 96% in *C. quadricarinatus* [39] are achieved. However, the system requires individual containers to be improved with regard to handling molting, feed system, monitoring of the species, the recirculation system automation, and use in seminatural ponds. In the same way, the individual containers are not only useful for enhancing the growth of *C. caementarius*, but also for the management of female reproduction, and in the case of shrimp males, also for selecting those with the highest rates of specific growth (>1% weight day^{-1}) for the purposes of genetic improvement.

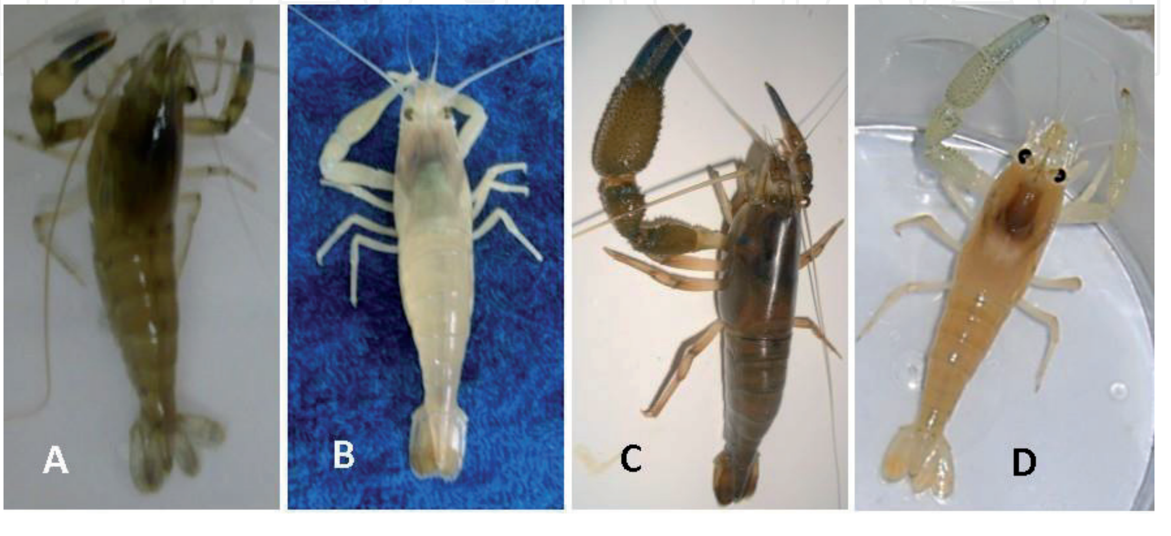

Figure 4.
Color of the C. caementarius body after culturing in individual containers: (A) female of normal color; (B) female depigmented; (C) male of normal color; and (D) male depigmented.

6. Co-culture of shrimp/tilapia

The co-culturing is done out with two species share a common aquatic environment (aquarium, tank, or pond), but whose construction does not allow physical interaction between organisms because they remain separate, and therefore, both species are a major management factor. Instead, in the polyculture, two or three species within the aquatic environment interact constantly competing for space and food, and therefore only one species is the main one.

Combinations of species in a co-culturing allow maximizing the performance of those who are territorial and aggressive. The co-culture of *Oreochromis niloticus* in cages inside ponds with *M. rosenbergii* [57] is well known. Also, it is known to co-culture of *C. caementarius* male shrimp in individual containers inside aquariums with *O. niloticus* fingerlings (**Figure 5**), where tilapia production was estimated at 0.511 kg m^{-3}. The tilapia consumed only food that came out of the shrimp culture container [12]. In other researches, co-culture of *C. caementarius* shrimp with tilapia *O. niloticus* at different densities were performed [58], and co-culturing shrimp with tilapia was performed to evaluate different concentrations of biological silage [55]. In both cases, 100% survival was achieved and production of species is improved. Co-cultivation of shrimp/tilapia mainly generates high nitrates that may be used in the cultivation of vegetables, whose integration would result in an aquaponics system.

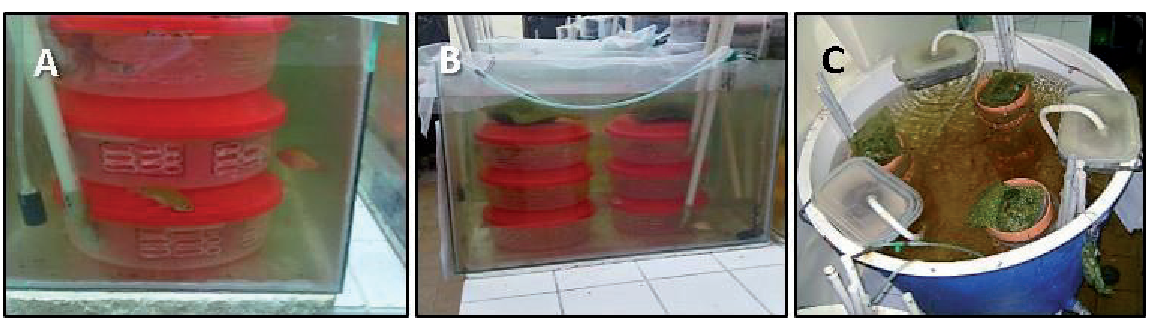

Figure 5.
(A) Co-culture of C. caementarius in individual containers with O. niloticus. (B) System of co-culture in aquarium. (C) Co-culture system in fiberglass tank.

7. Transportation of adult shrimp

The communal transport of male adult shrimps *C. caementarius* for fattening purposes is difficult due to the increased interaction causing injuries, chelipeds loss, shrimp death mainly of those who are about to carry out ecdysis or those who molt during the transport. In addition, the increased mortality depends on the density and transport time; but water temperature is a dominant factor that affects shrimp during transport [59].

The transport of adult *C. caementarius* shrimps in individual containers is performed by using plastic cups where a shrimp (≥4 cm of total length) is introduced into each plastic cup (250 mL). The plastic cup has holes to allow the water flow (**Figure 6A**). Then, all plastic cups are conditioned in plastic containers (45 L) with water of river (**Figure 6B**) and with either continuous or intermittent aeration (**Figure 6C**). The average water temperature is around 20°C. This system allows to transport 77 shrimps (17 shrimps for 10 L) per container for 5 h and with 100% survival [12]. However, the ideal size of transporting cups of live shrimps has not been studied, but as they support very small physical space, it is possible to use smaller plastic cups or to use PVC pipes according to the animal size.

Figure 6.
Transport system of live shrimps of C. caementarius. (A) Plastic cup with a shrimp. (B) Plastic cups put into a plastic container. (C) Aerator system.

On the other hand, the conventional transport of *C. caementarius*, an adult shrimp of 6 cm of total length, is also carried out in 4‰ of water salinity, because with this salinity, the shrimps do not show interaction or cannibalism and all survive in these conditions for 45 days [60]. The *M. rosenbergii* broodstock are transported in containers with brackish water (12‰), with oxygen and at low temperature to reduce metabolism, thus obtaining mortalities <10% [61]. In addition, aerated plastic barrels, or trucks with aerated water tanks, are used [62]. Other techniques such as increasing air humidity, the use of refrigerated sawdust or chips, and purging to reduce nitrogenous waste have been developed to increase the survival during transportation of live specimens of shrimp, prawns, lobsters, and crabs [63].

8. Conclusions

The male shrimps *C. caementarius* are aggressive for having one of the chelipeds more developed, causing greater interaction and cannibalism in any culture system. Female shrimps are less aggressive. To reduce interaction and shrimp cannibalism, two management systems are proposed. For postlarvae, using brackish water (12‰) keeps high survival (>85%) but only in the initial culture which lasts for 50 days. For the fattening of adult males, growing in individual containers conditioned in multiple levels allows high survival (87 and 100%) and yields between 0.7 and 1.0 kg m^{-2}. Furthermore, in this system, the co-culture of shrimp/tilapia is also performed to maximize performance. It is still required to demonstrate the technical and economic feasibility of fattening male shrimp in individual containers within seminatural ponds.

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Conflict of interest

The author has no conflict of interest.

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