









REVIEW

Recent advances on research of the native prawn *Macrobrachium americanum* (Decapoda: Palaemonidae) with aquaculture and conservation purposes

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ABSTRACT. There has recently been great concern for proper conservation and use of living natural resources where good management practices on aquaculture are mandatory. The economic and ecological importance of prawns of the Genus *Macrobrachium* cause an impact at a global level involving economic, academic and social aspects. *Macrobrachium americanum* appears as one of the genus species with high nutritional value and an economic demand in the national and international markets, as well as a vital income for fisherman and producers of this species. For researchers, it is a challenge to find solutions to culture and propose conservation measures for *M. americanum* with emphasis on development, nutrition and reproduction. Although there are scientific studies supporting the economic importance of this species, our knowledge about its cultivation, reproduction and conservation is limited. This paper summarizes the latest studies made in cooperation with *M. americanum* in research lead by the Centro de Investigaciones Biológicas del Noroeste, Mexico. After several years of continuous research, it is considered that those efforts have produced useful information for the sustainable exploitation, conservation and basic management practices of this species.

Key words: Freshwater ecosystem, growth rate, native prawn species, conservation, sustainable fishing.

Investigaciones recientes sobre el langostino nativo *Macrobrachium americanum* (Decapoda: Palaemonidae) con fines de acuicultura y conservación

RESUMEN. En los últimos tiempos ha existido una gran preocupación por la conservación y uso adecuados de los recursos naturales vivos, donde las buenas prácticas de manejo en la acuicultura son importantes. La importancia económica y pesquera de los langostinos del Género *Macrobrachium* causa un impacto a nivel global que incluye aspectos económicos, académicos y sociales. *Macrobrachium americanum* se presenta como una de las especies del género con alto valor nutritivo y demanda económica en el mercado nacional e internacional y constituye un importante ingre-

so para los pescadores y productores de esta especie. Para los investigadores es un desafío encontrar soluciones para la conservación del *M. americanum* con énfasis en el desarrollo, la nutrición y la reproducción. Aunque existen estudios científicos que avalan la importancia económica de esta especie, nuestro conocimiento sobre su cultivo, reproducción y conservación es limitado. Este artículo resume algunos estudios en colaboración sobre *M. americanum*, liderados por el Centro de Investigaciones Biológicas del Noroeste, México. Después de varios años de investigación continua, se considera que esos esfuerzos han producido información útil para la explotación sostenible, conservación y las posibles medidas de manejo para esta especie.

Palabras clave: Ecosistema de agua dulce, tasa de crecimiento, especie nativa de langostino, conservación, pesca sostenible.

INTRODUCTION

Freshwater prawns

The goal of aquaculture activity is the production of useful techniques for the rearing, cultivation and commercialization of aquatic animals and plants (Vega-Villasante and Chong 2006). Prawns or freshwater shrimps, which are the most diverse crustaceans within the Palaemonidae family, are of major importance in aquaculture. They have a wide geographic distribution including many species living in estuarine and freshwater ecosystems (Hernández-Sandoval 2008). Within this family, the Genus *Macrobrachium* Bate, 1868, has been of great interest due to the number of species it comprises (more than 230), its geographical distribution and its economic value in many countries (Vega-Villasante et al. 2011b; Méndez-Martínez et al. 2018b). Traditionally, several species of this genus have been cultured or extracted from rivers for human consumption owing to its good flavor and high protein content. Since they are omnivorous with carnivorous trends, there are many possibilities of developing diets with a variety of nutrients. According to Vega-Villasante et al. (2011a, 2011b), the Genus *Macrobrachium* is distributed in the tropical and subtropical regions around the world in areas where precipitation fluctuates between 400-1,350 mm a year. They may be found at sea level up to 800-1,500 m altitude, delimited by the isotherm of 18 °C, with minimum and maximum annual

temperature of 16 °C and 32 °C, respectively (Arroyo-Rentería and Magaña-Ríos 2001). Freshwater prawns can successfully live in rivers, estuaries, swamps and most kind of coastal water bodies (Valencia and Campos 2007). This ability and flexibility to live in a variety of habitats, makes prawns of this genus a good option to explore its potential for aquaculture.

In Mexico, several native species and one exotic (*Macrobrachium rosenbergii*) have been reported (Arredondo-Figueroa and Ponce-Palafox 2011). A total of 16 species have been registered in both sea sides of Mexico: in the Atlantic, bordering the Gulf of Mexico and the Caribbean Sea; and in the Pacific, from Baja California to Chiapas (Hernández et al. 2015).

In recent years, many freshwater prawn populations have decreased or disappeared due mainly to overfishing and water pollution. This phenomenon is particularly serious in river basins. García-Guerrero et al. (2013) described some actions required for the conservation of the species that, if accomplished, will benefit the communities settled on the banks of the rivers by providing them with protein-rich food. Unmanaged fisheries for this and other species should be stopped to allow their reproduction and conservation.

Macrobrachium americanum (Figure 1) is a prawn reaching a large size in the wild and is distributed in the Pacific coast from northern Mexico to Peru (Wicksten and Hendrickx 2003; Hernández et al. 2007; Méndez-Martínez et al. 2017) (Figure 2). There are some studies on the growth, nutrition, biochemistry, distribution and ecology of this species (Hernández et al. 2007;



Figure 1. *Macrobrachium americanum* adult male (left) and adult females (right) collected in Oasis San Pedro de la Presa, Baja California Sur, Mexico ($17^{\circ} 03' 36.14''$ N, $100^{\circ} 01' 35.03''$ W). Picture from Soberanes-Yepiz.

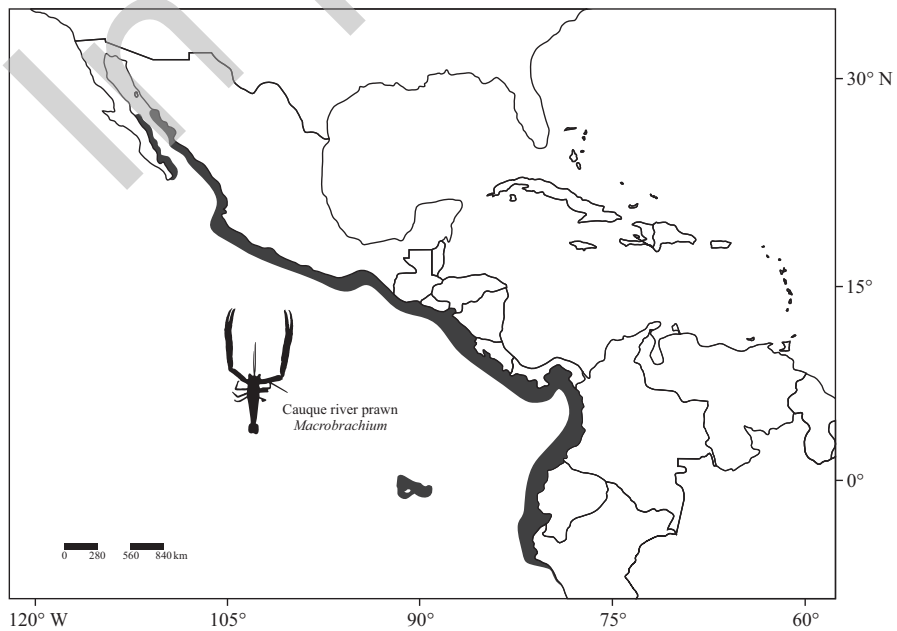


Figure 2. Geographic distribution of cauque river prawn *Macrobrachium americanum*.

García-Guerrero et al. 2011; Méndez-Martínez et al. 2018a; Soberanes-Yepiz et al. 2018; Soberanes-Yepiz 2020). However, it should be noted that there is little knowledge on culture practices or conservation goals. To address this issue, this study aims to present the latest advances on reproduction and nutrition of this prawn carried out by researchers of the Centro de Investigaciones Biológicas del Noroeste, S.C. (CIBNOR).

Economic facts of *Macrobrachium americanum*

At present, several research groups from CIBNOR La Paz, B.C. S. CUCOSTA Guadalajara and CIIDIR Oaxaca in Mexico, have performed several proposals to determine the biological or ecological features of *M. americanum*. This is a species of high economic value based on their taste, high protein content and appearance, which is expensive for cuisine (García-Guerrero et al. 2013; Méndez-Martínez et al. 2018a). Average prices per kilogram range between USD 2.61 to USD 6.55 in a local market depending on demand, size and quality of the product. Globally speaking, this market is supplied mainly by *M. rosenbergii*, an Asian native species commonly cultivated in countries such as India, China and Thailand, and exported to Europe, Asia and North America (García-Guerrero et al. 2013). In Latin America, *M. americanum* is one of the largest prawns of the genus with a maximum of 290 mm in total length (Méndez-Martínez et al. 2017). It almost reaches the size of *M. rosenbergii*, which is perhaps the largest species of this genus, with up to 320 mm in total length (Ibarra and Werthmann 2020). Therefore, the cultivation of *M. americanum* has become very attractive for aquaculture.

Recent research focused on *Macrobrachium americanum*

Studies carried out with sub-adults of *M. americanum* by López-Uriostegui et al (2020) revealed

that larger specimens were collected at sites with temperatures ranging from 26 °C to 29 °C and salinity from 3 to 10.5. Meanwhile survival decreased with temperatures above 30 °C and salinities greater than 10. An optimum level for survival was set at temperatures of 23-29 °C and a salinity from 0 to 5. In another research, Sainz-Hernández et al. (2016) observed that 29 °C seems to be the best temperature for egg rearing, since at this temperature eggs increased their volume by 50%, hatching rate was 100%, and larvae survived for a longer time. They also observed that at 26 °C eggs increased 25% in volume, 40% of the eggs hatched, and larvae died in early stages. Larvae of eggs incubated at 33 °C died one day after hatching.

Based on the study of physical and chemical parameters from two sampling sites (Coahuayan river with salinity of 1.03, and the artificial irrigation channel Zanja Prieta with salinity of 0.2 in Michoacán), which are natural habitats of *M. americanum* in Mexico, it is suggested that this prawn is a better option for culture on water with high alkalinity and total hardness in comparison with *M. rosenbergii* (García-Guerrero et al. 2013). The latter authors also reported adults *M. americanum* at temperatures as low as 21 °C, however, post-larvae were present only at temperatures above 25 °C. In general, *M. americanum* prefers to live under aquatic vegetation, rocks, crevices and holes or dug in the mud leaving their shelters to feed at night (González-Vera et al. 2018).

On the other hand, García-Guerrero and Hendrickx (2009) described the embryonic development of the species and found that the incubation period was 18 days at 24 °C. Likewise, García-Guerrero (2009, 2010) studied the proximal composition of eggs incubated at different temperatures and detected that the main source of energy were lipids and that proteins were the most abundant component. Regarding reproduction techniques, Aquíñaga-Cruz et al. (2012) showed that, even though eyestalk ablation of female *M. amer-*

icanum did not trigger reproduction, such procedure was recommended because the growth rate increased twice and the aggressiveness between animals was reduced, increasing survival.

Another research stated that *M. americanum* has effective dispersal capabilities due to its life history, including a pelagic larval stage and behavioral characteristics, such as positive phototaxis as a juvenile and the ability to disperse in terrestrial environments (García-Guerrero et al. 2013). On the other hand, McNamara et al. (1983) observed little tolerance of first larval stages of *M. americanum* to salinity on survival, respiratory rate and molting. García-Guerrero and Apun-Molina (2008) evaluated the effect of density and the use of shelters on the survival and growth of juveniles and concluded that those kept at low density and with shelter had better growth. Additionally, García-Guerrero et al (2011) studied the oxygen consumption of specimens and corroborated that both the temperature was the determining factor, and that the mass-specific oxygen consumption rate of small prawns was higher than that of large prawns for all of the temperatures studied.

In relation to nutritional studies, Pérez-Rodríguez et al. (2018) analyzed the effect of five diets with different amounts of crude protein (27, 33, 38, 43 and 48%) on growth and survival of wild *M. americanum* prawns. The option with 33% protein level resulted in the best treatment for the experimental design they followed.

Another important issue considered was eating habits. Despite its daytime feeding preferences, Lopez-Uriostegui et al. (2017) noticed that *M. americanum* can be fed also at night or during the dark period. Therefore, it is recommended to offer food at both scenarios for this prawn, while for species such as *M. tenellum*, feeding must be given only during the light period.

Santamaría-Miranda et al. (2018) studied the polyculture of *M. americanum* prawn and tilapia (*Oreochromis niloticus*) with different densities, finding that their polyculture at room temperature

in freshwater with a density of 14: 5 (tilapia: prawn) was like monoculture with beneficial effects for both species.

Advances in reproduction and nutrition

Pérez-Rodríguez (2017) evaluated the effects of three diets (Camaronina 35 Purina®, 100% pelletized commercial food, and a 50:50% of food: fresh food with sardine and squid meat) on spermatophore production and sperm quality. Prawns (15-130 g weight interval) were collected in the oasis of San Pedro de la Presa, Baja California Sur, Mexico. Specimens were fed daily for 244 days under controlled laboratory conditions and sampled every 24 days. Results showed no significant differences caused by diet between sperm quality variables and reproductive exhaustion (decrease in spermatophore weight, percentage of sperm produced and increase in the average number of dead sperm). Additionally, a comparison with specimens recently captured from the wild in July 2017 revealed that all sperm quality variables were significantly higher in wild specimens than in specimens kept in controlled laboratory conditions. Since no significant differences in sperm quality were observed between the three diets and considering that the pellet is less expensive and easier to use than pelletized food, the former is more recommended for feeding reproductive *M. americanum* males. However, morphological or anatomical aspects of this reproductive structure still need to be clarified.

In addition, Yamasaki-Granados et al. (2012) evaluated the larval survival for different combinations of stocking density and feeding from larvae cultivated in green water. From these combinations, larvae fed with *Artemia* nauplii at a density of 50 larvae l⁻¹ had the highest survival. Currently, supplies of juveniles are limited because hatchery and laboratory-reared larvae are difficult to raise.

Méndez-Martínez (2017) performed three related experiments with larvae and juveniles of

M. americanum obtained under laboratory conditions from the spawning of wild females. Experiments consisted of the evaluation of the effect of *Artemia* nauplii enriched with microalgae on the growth and survival of *M. americanum* larvae. Three different diet combinations were used. Those larvae fed with *Artemia* metanauplii I enriched with *Chaetoceros calcitrans* diet achieved the highest survival and growth. In Experiment II, the effect of four concentrations of crude protein (30.7, 37.2, 41.8 and 46.8%) in the diet on the productive response, proximal composition, and body amino acid of juvenile *M. americanum* was determined. Survival was 100% in all treatments. Dietary protein content had a significant effect on the proximal composition and the amino acid profile. Under experimental conditions, prawns fed with 37.2% crude protein diet reached a significantly highest final weight. In experiment III, the effect of different levels of protein (35 and 4%) and lipids (6, 10 and 14%) in the diet with factorial arrangement (3×2) was evaluated for six protein/energy relationships (17, 18, 19, 20, 21, and 22 mg kJ⁻¹ g⁻¹). The effect on productive and nutritional variables such as hepatopancreas cytology, biochemical and hematological composition was evaluated. Results showed that the diet containing 35% protein and 10% lipids with a P/E ratio of 18 mg kJ⁻¹ g⁻¹ seemed to be optimal for juveniles. It has been demonstrated that a proper amount of dietary protein is helpful to minimize cannibalism (Mendez-Martinez 2017). Since *M. americanum* has carnivorous trends, it can be assumed that this will also work with this species.

On the other hand, Raso-Ramírez (2019) carried out a population genetic study of this prawns with specimens from Baja California Sur (Oasis San Pedro de la Presa, La Paz, BCS) and from the Coyuca river, Guerrero (Coyuca de Benítez, Gro.). The main purpose was to evaluate the variation and genetic structure in two sites with different environmental conditions using primers for three mitochondrial genes (16S rDNA, COI

mtDNA, and control region). Results indicated that genetic diversity was within the interval normally observed for other decapod crustacean species and other *Macrobrachium* species, showing high values ($Hd = 0.99$; $\pi = 0.011$). The genetic diversity observed in some sites of the two places (BCS and Gro.), indicated them as potential places for the conservation tasks, and both seemed to be proper locations for future genetic management programs as well as for the development of cultivation biotechnologies. In this study, values of genetic differentiation (ϕ_{st}) were low and significant ($\phi_{st} = 0.006-0.2$). Results of ANOVA did not indicate the existence of two or more genetically different populations.

In another study carried out by Soberanes-Yepiz (2020), adult specimens of *M. americanum* were sampled in the Coyuca river, Guerrero, México (August to September 2015) and the Oasis of San Pedro de La Presa, BCS (June 2017 to October 2018). The author reported a positive allometric growth for males ($b > 3$) and a negative allometric growth for females ($b < 3$), finding that female weight was a better predictor of total fertility of *M. americanum* than length. The resulting equation describing the relationship between weight and fecundity of females was: Fertility (as number of eggs) = $1,863.6 W_t^{-23482}$. Regarding the experimental diet in terms of oxidative stress prevention, it was suggested that a suitable diet for juveniles should have a protein/lipid ration of 35/10. According to the gonadal stage, four stages were identified: previtellogenesis, early vitellogenesis, late vitellogenesis, and spawning. Reproduction occurred mostly during the rainy season (from July to October), and ovigerous females appeared mainly from September to October.

Therefore, *M. americanum* females are considered multiple spawners. This suggests that the main period of capture of *M. americanum* prawns occurs during the rainy season coinciding with the pick of reproduction. Currently, there is no regulation at all for their capture, which has caused a significant decline in their populations

in both places (García-Guerrero et al. 2013, 2015). Because of this, the total annual catch is reducing every year, which is no longer a good business for local fishermen. Consequently, they look for a variety of other activities, different from fishing. It is considered that a permanent monitoring of this living resource is required, as well as continuing the research on reproductive and feeding behavior aspects of this prawn both in the wild and in laboratory to propose and execute measures that promote its conservation through sustainable management.

CONCLUDING REMARKS

There are several studies, most of them carried out with the Genus *Macrobrachium* at the Centro de Investigaciones Biológicas del Noroeste S.C., based on culture improvement, larval production juvenile feeding, reproduction techniques, assays on growth and survival in ponds or tanks. The study of native aquatic species like *M. americanum* is of great importance because they are key elements in the recirculation of energy in fragile and degraded ecosystems that are of primary social and economic significance. Although there are several studies on this species, it is required to investigate on the relationship between density, stocking size and the growth under mono and polyculture conditions. Most research efforts focused on domestication by selecting best features or attributes that makes the species valuable, like low aggressiveness and large size.

Studies on genetics are required to select specimens with higher growth rate, since only prawns of 50 to 60 g were obtained in farming systems of rustic ponds. *M. americanum* seems to be a species with good potential for commercial culture, given its large size and high market price. This last should encourage researchers and justify financial support to study this species. Finally, we found that, after several years of continuous

research by researchers from different countries (Mexico, Costa Rica, Brazil, Ecuador, USA), those efforts have produced useful information for the sustainable exploitation and prevention of disappearance of this species.

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