The Tilapia-Prawn Polyculture: Its Development in Mexico

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ABSTRACT
Objective: To analyze the productive development performed by two aquatic species of recent introduction in Mexico, the giant freshwater prawn (Macrobrachium rosenbergii) and tilapia (Oreochromis niloticus), arguing their potential under mono- and poly-culture systems.

Design/Methodology/Scope: The bibliographic meta-analysis was developed searching information on the internet, and is presented in a chronological manner with the analysis of the technological, social and political dimensions, visualizing the benefits and advantages of applying the polyculture production system.

Results: A database on the development of the tilapia-freshwater prawn polyculture in our country was obtained. Mexico presents the required physical characteristics for both species productions. Thus, polyculture allows the use of the same infrastructure, resulting in a better productivity and income.

Limitations of the study/implications: Polyculture information registered on electronic media was scarce.

Findings/Conclusions: The polyculture production of the Malaysian prawn and tilapia is a profitable option for the aquaculture producer in tropical areas of Mexico.

Keywords: integrated management, Macrobrachium, Oreochromis, profitability increment.

INTRODUCTION
The utilization of aquatic resources dates from pre-historic times to the present. There is sufficient consensus and evidence to confirm that hunting, gathering and fishing sustained human groups since prehistoric times and allowed them to expand globally (Nash, 2011). Just as agriculture and animal domestication became a fundamental step in the development of humanity, aquaculture might have followed a similar process. First, the confinement of species appeared followed by the development of techniques for their reproduction and handling in controlled conditions. This is shown by evidence that dates back before 3000 b. C., mainly in Asian regions (Jones, 1986; Rabanal, 1988; Nash, 2011). A similar process probably occurred in Mesoamerica. The first aquatic organisms that man used came from water bodies (fresh, sea and marsh water), which are still abundant in the territory (CEDERSA, 2007).
Throughout Mexican history, aquacultural activities were developed and consolidated by Olmecs, Purepecha, Mexica and Chichimeca groups (Gutiérrez-Yurrutia, 1999). Following the conquest, use of natural resources underwent important changes. Notwithstanding, it was not until the time of Mexican Independence, in particular the Porfirian period, that the Mexican State took the first steps to incorporate aquaculture in the national agenda (Gutiérrez-Yurrutia, 2000; Contreras-Alvarado, 2012; Cupul-Magaña and Cifuentes-Lemus, 2016). Thus, by order of the Office of President Porfirio Díaz, the first pisciculture treatise was prepared and published in Mexico (Cházari, 1884). Since then, the establishment of aquaculture centers was promoted to foster the development of trout and carp (Cupul-Magaña and Cifuentes-Lemus, 2016). During the last five decades, aquaculture has enjoyed significant support; this sector that produces food of animal origin is the one with more rapid growth in the primary sector (FAO, 2016). The productive development that is reached based on the technological, social and political dimensions of the tilapia (O. niloticus) and giant river prawn (M. rosenbergii) cultures in order to finally bring an insight on the application and benefits attained by the polyculture of both species in Mexico.

RESULTS AND DISCUSSION

Prawn Culture Background

Utilization aspects of both cultures and that of prawn as a natural resource are submitted; public policies, infrastructure, social organization and places with foreseeable productive potential are included. Table 1 shows a timeline for both cultures in Mexico and their international development.

Currently, the Mexican fishery of river prawn is based on the utilization of four main species, all of the Macrobrachium genus: two in the Gulf of Mexico region (M. carcinus and M. acanthurus) and two in the Pacific region (M. tenellum and M. americanum) (Cifuentes-Lemus et al., 1997). These organisms live in tropical and subtropical places, in fresh and braquish water, they are omnivorous, detritophages, saprophages and cannibals and accept artificial food (Mayorga-Castañeda, 2011).

In December 1972, the General Directorate of Fisheries Planning and Promotion of the Ministry of Industry and Trade suggested a visit to the states of Michoacán and Guerrero by a group of persons from the Food and Agriculture Organization of the United Nations (FAO) and the National Community Development Institute (INDECO) by the Mexican Government (Balbuena, 2014). Since this visit, the river prawn (M. rosenbergii) was introduced to Mexico in 1973 and then again in 1978 (Figure 1). The Fisheries Department built three aquaculture centers: “El Real” in Veracruz, “El Carrizal”

<table>
<thead>
<tr>
<th>Decade</th>
<th>River prawn</th>
<th>Tilapia</th>
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<tbody>
<tr>
<td>1950</td>
<td>The controlled culture of M. rosenbergii began in Maysia</td>
<td>Species studied by the academy in different parts of the world</td>
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<tr>
<td>1960</td>
<td>In Hawaii, USA, the productive foundations for its cultivation were established</td>
<td>A prawn species was introduced in Mexico in order to repopulate big basins</td>
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<tr>
<td>1970</td>
<td>The river prawn was introduced in Mexico and the infrastructure for its development was built</td>
<td>Its culture begins as a social support species; the species is studied in academic institutions</td>
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<td>1980</td>
<td>International congresses are organized and it is included in educational programs</td>
<td>It is consolidated as one of the most important species in Mexico and the world</td>
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<tr>
<td>1990</td>
<td>Production and fattening units are operated in Mexico and Latin American countries</td>
<td>One of the species of greater production at an international level; congresses are organized in Mexico and abroad.</td>
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<tr>
<td>2010</td>
<td>Monoculture production: The polyculture of tilapia begins</td>
<td>It is the culture fish with most economic importance in Mexico</td>
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<tr>
<td>2020</td>
<td>New post-larva production units are established and its production is encouraged</td>
<td>Species of great importance, with social culture and industrial organizations</td>
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in Coyuca de Benítez, Guerrero, and “Chamela” in Sinaloa. Its objective was to produce post-larvae with a technique named “green water”. In that same decade, the Papaloapan Commission, an instance of the Federal Government, boosted the first attempts to cultivate one of the most important species in the zone in Veracruz: freshwater prawns (*Macrobrachium acanthurus*); for this, it built an aquaculture station on the side of the Los Amates lagoon, on the riverside of the Papaloapan River, in Tacotalpan, Veracruz (Cabrera-Cano, 1977).

Since its introduction in 1973 to present, the river prawn has attained good productive results. However, it has not attained the expected ones (New, 2009). Experiments have been made on native prawns such as freshwater prawn (*Macrobrachium acanthurus*) and freshwater prawn *M. carcinus* (Cabrera-Cano, 1977), although results have not been encouraging either. The national fishery of fresh water crustacean species that occupy the same market niche as *M. rosenbergii* is almost depleted (Espinosa and Rodríguez, 1986; Lorún-Núñez, 2017). The available information for native species of Latin America includes biological, ecological and sometimes controlled culture aspects, but little is known about the fishery utilization or the actual state of populations (García-Guerrero et al., 2013; Lorún-Núñez, 2017). Traditionally, the fishing art used to capture prawns are traps; the best capture opportunities happen during the mating period as it is then that mostly females migrate to release larvae near the coast (García-Guerrero et al., 2013). As these carry eggs adhered between the pleopods, their extraction implies a loss of the offspring.

In contrast, the river prawn *M. rosenbergii* is a studied domesticated species cultured successfully in several parts of the world (New, 1995; Cifuentes-Lemus et al., 1997). Therefore, the development of its culture is an alternative to meet the demand and decrease the pressure that fishing exerts on prawns as a natural resource. (Asiain-Hoyos et al., 2013). Since 2014, the river prawn offspring production, which is the first link in the agri-food chain, is addressed in the state of Veracruz by organized producer groups (Acuacultores Veracruzoanos A.C., AVAC), and research institutions (Tecnológico Nacional de México-Instituto Tecnológico de Boca del Río and Colegio de Postgraduados, Veracruz Campus) (Benítez-Hernández et al., 2016). Currently, there is a post-larvae production unit for river prawn in the state of Oaxaca. Another unit in the state of Guerrero supplies post-larvae intermittently to the state of Morelos (Figure 2). Currently, the limited offer of post larvae endangers the entire industry.

**Tilapia Culture Background**

Tilapia is the name for several species of African species belonging to the *Oreochromis* genus; most of them inhabit tropical regions in the planet where environmental conditions are favorable for their reproduction and growth (Morales-Díaz, 1991). By initiative of the Papaloapan Commission and as an option to detonate development, tilapia was introduced in Mexico to consolidate fisheries in great basins (Asiain-Hoyos, 2009). As of 1965, broods were cultured in the Miguel Alemán dam in Temascal, Oaxaca and other water bodies of the same type throughout the country. From 1972 to 2014, it is estimated that more than one million tons of tilapia have been captured in national basins. In 1999, the General Directorate of Aquaculture had 27 aquaculture centers for the reproduction of tilapia broods in the states of Aguascalientes, Coahuila, Colima, Chiapas, Chihuahua,
Durango, Guanajuato, Guerrero, Jalisco, Michoacán, Morelos, Nayarit, Oaxaca, Querétaro, Sinaloa, Tabasco, Tamaulipas, Veracruz, and Zacatecas. Today, tilapia *O. niloticus* is the main aquaculture species cultured in the country, with presence nationwide and a production of more than 100 000 t per year (CONAPESCA, 2014; Ventura *et al*., 2014).

**The Tilapia-Prawn Culture**

Aquaculture is a productive activity oriented to producing food. As a strategy for attaining yields and the use of infrastructure, diverse production technologies have been developed (Navarrete-Salgado *et al*., 2000). Polyculture consists in culturing a main species, generally with greater population density or dominance, and the inclusion of one or more additional species to the existing one in order to use resources available in the pond with greater efficiency (García-Guerrero *et al*., 2013). The use of several trophic niches is the reason why the polyculture has been successful. The tilapia-prawn polyculture has a net yield above the tilapia monoculture (Alvarez-Torres *et al*., 1999; Asiain-Hoyos *et al*., 2013). Because of its capacity to improve water quality, tilapia sets a control on the flourishing of phytoplankton and the accumulation of organic matter (Massaut *et al*., 2004; Flores, 2010). Income obtained from the production if tilapia may cover operational expenses of polyculture, as well as providing an earning margin in income from the culture of shrimp which represents the net profits of culture (Espinosa-Chaurand *et al*., 2011), which allows performing the production, as each species occupies different ecological niches. Tilapia-Prawn polyculture organisms help each other: the level of dissolved oxygen is stabilized, predators are reduced, there is greater total productivity of the pond, fish and crustaceans perform cross coprophagy, produce greater financial value per culture, among others (Hernández-Barraza, 2011). Hishamunda (2003) and Navarrete-Salgado (2017) describe some advantages offered by integrated pisciculture: the cost per organism is reduced; allows establishing preservation methods for the later sale in neighboring markets; ponds use lands not suitable for agricultural activities; the production may be calculated according to needs; growth and the fattening of fish and crustaceans is controlled; this is adequate for genetic handling; only species cultured in ponds are developed; the presence of predators and competitors is avoided; last, natural mortality is minimized.

Although there are different polyculture models with different species (Tafur-Gonzalez *et al*., 2009), in all cases, the different strata and pond resources are utilized with more efficiency (Sanabria, 2016). In the 1980s, different aquaculture farm models with catfish, trout, tilapia and carp were developed in Mexico. Also, smaller fish were used and the cage strategy was implemented to assure and control the population. All sorts of studies were performed. However, as no polyculture projects were implemented, the system’s advantages were not utilized (Ventura *et al*., 2014). This way, the polyculture of these two species is feasible and recommended to elevate yield per surface unit and hence profitability. An example of a polyculture is found in Tezonapa, Veracruz, México (Figure 3). It does not increase operating costs or infrastructure significantly. Work with the same labor and energy requirements or aeration equipment is used (Ponce *et al*., 2005).

**CONCLUSIONS**

Mexico has been a fishing and aquacultural country since pre-Hispanic times. Tilapia was introduced to the country more than 50 years ago and river prawn more than 40 years ago. Currently, the production of both species as a mono- and polyculture is a reality. Increases in production volumes will depend on the sufficient supply of broods of both species, as the market

*Figure 3. Tilapia-Prawn polyculture pond in Tezonapa, Veracruz, Mexico.*
is well established. In polycultures, both species benefit from their mutual relationship, which results in greater yield and profits per productive cycle. The tilapia culture tradition already overcame a generation of producers in the tropical region of Mexico. In contrast, river prawn did not have the same luck; notwithstanding, its market and current boost of new production units of post-larvae generates a new perspective. In the infrastructure installed for the production of tilapia, developing the polyculture with both species is feasible. This activity overcomes monoculture income. Therefore, it has the potential to increase the wellbeing of aquaculturists in the tropical regions of Mexico.

REFERENCES


