https://doi.org/10.32854/agrop.v13i11.1808

The Tilapia-Prawn Polyculture: Its Development in Mexico

Asiain-Hoyos, Alberto[1]; Reta-Mendiola, Juan Lorenzo[1*]; García-Sánchez, Alejandra Ivonne[1]; Domínguez-Mora, Javier[1]

[1]Colegio de Postgraduados, Veracruz Campus. Carretera Xalapa-Veracruz km 88.5, Tepetates, Manlio Fabio Altamirano, Veracruz, Mexico. C. P. 91690.
***Corresponding Author**: jretam@colpos.mx

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 data base 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).

Agroproductividad: *Vol. 13, Núm. 11, noviembre. 2020. pp: 31-36.*
Recibido: *abril, 2020.* **Aceptado:** *octubre, 2020.*

Imagen de Sirawich Rungsimanop en Pixabay

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 two aquatic species of recent introduction to the country, giant river tilapia (*Macrobrachium rosenbergii*) and tilapia (*Oreochromis niloticus*), have exhibited their potential for mono- and polyculture systems.

MATERIALS AND METHODS

For this analysis, a literature review in electronic meta engines available at the Digital Library of Colegio de Postgraduados for 2019 (http://www.biblio.colpos.mx/portal/index.php/colpos-digital.html), such as Academia.edu, Science Research, Jurn, Redalyc and Scielo was developed. The information is submitted in chronological order, from basic literature on aquaculture in Mexico to our days. The conclusion 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 forseeable 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 1. Timeline per decade of evolution for tilapia and prawn in Mexico and internationally.

Decade	River prawn	Tilapia
1950	The controlled culture of *M. rosenbergii* began in Maysia	Species studied by the academy in different parts of the world
1960	In Hawaii, USA, the productive foundations for its cultivation were established	A prawn species was introduced in Mexico in order to repopulate big basins
1970	The river prawn was introduced in Mexico and the infrastructure for its development was built	Its culture begins as a social support species; the species is studied in academic institutions
1980	International congresses are organized and it is included in educational programs	It is consolidated as one of the most important species in Mexico and the world
1990	Production and fattening units are operated in Mexico and Latin American countries	One of the species of greater production at an international level; congresses are organized in Mexico and abroad.
2010	Monoculture production. The polyculture of tilapia begins	It is the culture fish with most economic importance in Mexico
2020	New post-larva production units are established and its production is encouraged	Species of great importance, with social culture and industrial organizations

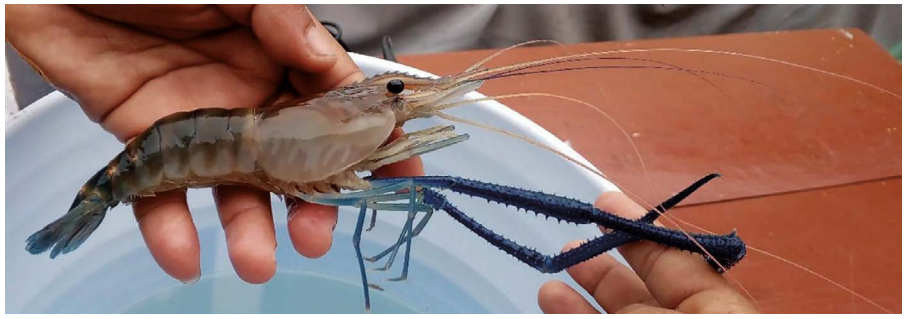

Figure 1. Male river prawn (*Macrobrachium rosenbergii*) breeder.

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 (*M. Acanthurs*) 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 cost (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 Veracruzanos 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,

Figure 2. Harvest of river prawn *M. rosenbergii* in Jojutla, Morelos, Mexico.

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-Gonzales *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

Alvarez-Torres, P., Ramírez-Martínez, C. & Orbe-Mendoza, A. (1999). Desarrollo de la acuacultura en México y perspectivas de la acuacultura rural. Taller ARPE, FAO-UCT, 09-12 Noviembre, 1999. 38 p. Recuperado de: http://cesaem-morelos.org/descargas/DesarrolloAcuaculturaenMexico.pdf

Asiain-Hoyos, A. (2009). Technology transfer for commercial aquaculture development in Veracruz, Mexico. PhD Thesis. University of Stirling. 288 p. Recuperado de: https://dspace.stir.ac.uk/handle/1893/1723#.XvaCcShKhPY

Asiain-Hoyos, A., Fernández-Díaz, B., Reta-Mendiola, J.L., Delgadillo-Tiburcio, M.S., Platas-Guevara, F. & Suárez-Santa-Cruz, C.A. (2013). Manual de policultivo langostino malayo-tilapia. Fundación Produce Morelos A.C. y Colegio de Postgraduados, México. 36 p.

Balbuena R., E.D. (2014). Manual básico sobre procesamiento e inocuidad de productos de la acuicultura. FAO. San José. Costa Rica. http://www.fao.org/3/a-i3835s.pdf

Benítez-Hernández, J., Reta-Mendiola, J., Asiain-Hoyos, A. Ruiz-Rosado, O. Campos-Arriaga, L. & Montané-Azpiri, J. (2016). Modelo de toma de decisiones de abasto de agua en una comunidad rural. Agroproductividad 9:1-19. http://revista-agroproductividad.org/index.php/agroproductividad/article/view/828/692

Cabrera-Cano, G.M. (1977). Biología y cultivo de *Macrobrachium acanthurus* wiegmann (1836) en el bajo Papaloapan. Tesis Licenciatura. Escuela Nacional de Ciencias Biológicas. Instituto Politécnico Nacional, México. 148p.

Cházari, E. (1884). Piscicultura en agua dulce. Secretaría de Fomento. México. 828p.

Cifuentes-Lemus J.L., Torres-García, M.D.P. & Frías-Mondragón, M. (1997). El océano y sus recursos: XI. Acuacultura. 2a. ed. Fondo de Cultura Económica. México. 98 p. http://www.bio-nica.info/Biblioteca/Cifuentes1997.pdf

CONAPESCA (Comisión Nacional de Acuacultura y Pesca). (2014). Anuario estadístico de acuacultura y pesca. CONAPESCA-SAGARPA, México. 260p. https://www.conapesca.gob.mx/work/sites/cona/dgppe/2014/ANUARIO_ESTADISTICO_DE_ACUACULTURA_Y_PESCA_2014.pdf

Contreras-Alvarado, M. (2012). Los inicios de la piscicultura en México: Actores y redes (1883-1892). Tesis M.C. Centro de Investigaciones Económicas, Administrativas y Sociales. Instituto Politécnico Nacional, México. 120 p. https://tesis.ipn.mx/bitstream/handle/123456789/14271/2012%20MINERVA%20CONTRERAS%20ALVARADO.pdf?sequence=1&isAllowed=y

Cupul-Magaña, F.G. & Cifuentes-Lemus, J.L. (2016). El primer libro formal de piscicultura en México. Piscicultura de agua dulce de Estéban Cházari (1884). Acta Pesquera 6:1-5. http://www.enip.com.mx/ap6-1.pdf

Espinosa, J.L. & Rodríguez, A. (1986). El langostino: Un alimento en peligro. Serie Medio Ambiente en Coatzacoalcos. Volumen X. Centro de Ecodesarrollo. México. 96 p. https://cdigital.uv.mx/bitstream/handle/123456789/4973/mac10lan.pdf?sequence=2&isAllowed=y

Espinosa-Chaurand, L.D., Vargas-Ceballos, M.A., Guzmán-Arroyo, M., Nolasco-Soria, H., Carrillo-Farnés, O., Chong-Carrillo, O. & Vega-Villasante, F. (2011). Biología y cultivo de *Macrobrachium tenellum*: Estado del arte. Hidrobiológica 21:98-117. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0188-88972011000200001

FAO (Organización de las Naciones Unidas para la Agricultura y la Alimentación). (2016). El estado mundial de la pesca y la acuicultura. FAO. p. 23. http://www.fao.org/3/i9540es/i9540es.pdf

Flores, P. (2010). Plan de negocios para la producción simultánea de pez de tilapia y camarón de agua dulce de la especie *Oreochrosmis niloticus* y *Macrobrachium rosembergii*, en el departamento de San Vicente, El Salvador. Carrera de Administración de Agronegocio. Noviembre 2010. 64p. https://bdigital.zamorano.edu/bitstream/11036/5612/1/AGN-2010-T008.pdf

García-Guerrero, M.U., Becerril-Morales, F., Vega-Villasante, F. & Espinosa-Chaurand, L.F. (2013). Los langostinos del género *Macrobrachium* con importancia económica y pesquera en América Latina: Conocimiento actual, rol ecológico y conservación. Latin Am. J. Aquatic Res. 41: 651-675. http://dx.doi.org/103856/vol41-issue4-fulltext-3

Gutiérrez-Yurrutia, P.J. (1999). La acuicultura en México: I. Época Prehispánica y Colonial. Biología Informa 29: 3-7. https://www.researchgate.net/publication/256458517_La_acuicultura_en_Mexico_I_Epoca_prehispanica_y_colonial

Gutiérrez-Yurrutia, P.J. (2000). La acuicultura en México: II. Época actual y perspectivas. Biología Informa 31: 1-8. https://www.researchgate.net/publication/256458397_La_acuicultura_en_Mexico_II_Epoca_actual_y_perspectivas

Hernández-Barraza, C.A. (2011). Evaluacion del crecimiento de camarón blanco del pacífico (*Litopenaeus vannamei*) en policultivo con tilapia roja (*Oreochromb mossambicus* × *O. niloticus*) bajo un sistema de recirculación de agua. CienciaUAT 5(3): 41-45. https://www.redalyc.org/articulo.oa?id=4419429230078idioma=es

Hishamunda, N. (2003). Desarrollo de la acuicultura en China: Función de las políticas del sector público. FAO Documento Técnico de Pesca 427. Recuperado de: http://www.fao.org/3/Y4762S/Y4762S00.htm

Jones, A. (1986). Historical background, present status, and future perspectives of the aquaculture industry on a worldwide basis. IFAC Automation and Data Processing in Aquaculture 20(7) :1-9. https://doi.org/10.1016/S1474-6670(17)59149-1

Lorún-Núñez, R.M. (2017). Observaciones de la pesquería de langostino (*Macrobrachium* sp.) en el estado de Veracruz, México. Ciencia Pesquera 25: 31-34. https://www.gob.mx/cms/uploads/attachment/file/299050/Ciencia_pesquera_25_2__noviembre_2017_05.pdf

Massaut, L., Rodríguez, R. & Del Mar, C. (2004). El efecto de la tilapia sobre la producción de camarón bajo condiciones de mancha blanca. Comunicación Científica CIVA: 706-712. https://www.researchgate.net/publication/318135299_El_efecto_de_la_Tilapia_sobre_la_produccion_de_Camaron_bajo_condiciones_de_mancha_blanca

Mayorga-Castañeda, F.J. (2011). Acuerdo por el que se da a conocer la Carta Nacional Acuícola. Diario Oficial de la Federación 11/06/2018, México. 50p.

Morales-Díaz, A. (1991). La tilapia en México: biología, cultivo y pesqueria. AGT Editor S.A. 1a ed. México. 190 p. Recuperado de: https://www.libcientifica.com/libro/la-tilapia-en-mexico_113489

Nash, C.E. (2011). The history of aquaculture. Wiley-Blackwell, USA. 228 p. DOI:10.1002/9780470958971

Navarrete-Salgado, N.A. (2017). Chirostoma (menidia): ecología y utilización como especie de cultivo en estanques rústicos. BIOCYT: Biología Ciencia y Tecnología 10: 736-748.

Navarrete-Salgado, N.A., Fernández, G.E., Contreras R., G. & Rojas B, M. (2000). Policultivo de carpas y tilapia en bordos rurales del estado de México. Hidrobiológica 10: 35-40.

New, M.B. (1995). Status of freshwater prawn farming: a review. Aquac. Res. 26: 1-54. http://www.revistaaquatic.com/aquatic/pdf/37_9.pdf

New, M.B. (2009). History and global status of freshwater prawn farming. pp. 1-11 In: New, M.B., Valenti, W.C., Tidwell, J.H., DÁbramo, L.R., Kutty, M.N. (eds.). Freshwater prawns: biology and farming. Blackwell Publishing, USA. 544 p.

Ponce, D., Hernández, E. & Gasca, E. (2005). Viabilidad económica del policultivo de tilapia nilótica y langosta australiana en el estado de Yucatán, México. Documento de Trabajo 2005-03. PhD. Fac. CC. Económicas y Empresariales, Universidad de La Laguna; Fac. CC. Económicas y Empresariales, Univ. de Las Palmas de Gran Canaria, España. 22 p. Recuperado de: https://accedacris.ulpgc.es/bitstream/10553/1583/1/699.pdf

Rabanal, H.R. (1988). History of aquaculture. ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Manila, Philippines. 17 p.

CEDERSA (Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria) (2007). Metaevaluación de programas de la SAGARPA dirigidos a productos agrícolas básicos. Resultados generales. Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria. Cámara de Diputados. LX Legislatura. Congreso de la Unión. México, 1a ed. agosto, 2007. CDMX, México 349 p. Recuperado de: http://biblioteca.diputados.gob.mx/janium/bv/cedrssa/lx/met_progsag_prodagri.pdf

Sanabria, Y.A.P. (2016). Historia de la acuicultura en Colombia. Revista AquaTIC 37:60-77.

Tafur-Gonzales, J., Alcántara-Bocanegra, F., Del Águila-Pizarro, M., Cubas-Guerra, R., Luis, M.-P. & Chu-Koo, F.W. (2009). Paco *Piaractus brachypomus* y gamitana *Colossoma macropomum* criados en policultivo con el bujurqui-tucunaré, *Chaetobranchus semifasciatus* (cichlidae). Folia Amazónica 18: 97-104.

Ventura, M., Buchaca, T., Buñay, D., Larsen, T., Pla-Rabes, S., Sabas, I., Vila-Costa, M. & Miró, A. (2014). Efecto de la introducción de peces en la conservación de anfibios y crustáceos de lagos de alta montaña. Integrative Freshwater Ecology 1: 215-230.

AGRO PRODUCTIVIDAD