OPEN ACCESS
International Journal of Aquatic Science
ISSN: 2008-8019
Vol. 6, No. 1, 67-83, 2015

IJAS

The genus *Chirostoma* (Actinopterygii: Atheriniformes) in Mexico: Challenge for conservation and aquaculture technology

Andrea Fernanda Hernández-Batista, José Alberto Ramírez-Torrez, Alejandro Azaola-Espinosa Lino Mayorga-Reyes and María del Carmen Monroy-Dosta*

Universidad Autónoma Metropolitana-Xochimilco. Depto. El Hombre y su Ambiente Calzada del Hueso No. 1100. Col. Villa Quietud. México

Received: 12 May 2014 **Accepted:** 20 August 2014 **Published:** 03 January 2015

Abstract: Aquaculture and fisheries represent an important factor in the development of many worldwide communities and in small and large-scale activities for only the 8% of world population. Considering the small-scale fisheries and aquaculture activities as income and animal protein sources of people who work in these habitats, it is unavoidable to take into account economic, social and cultural aspects. Usually this type of activities uses endemic species, as in the case of Mexico, with genus *Chirostoma* (commonly called white fish or "charales"), which many Mexican families depend almost exclusively on their extraction. Today this genus faces serious problems due to overexploitation, habitat loss and the introduction of exotic species. The most viable option for recovery and subsequent commercial production is the culture and cleaning up of their habitat. In the first case are already made significant efforts for cultivation, however, nothing has been done by the second problem. The goal of this paper is show the present state of the species of the genus *Chirostoma*, giving options to improve their current condition.
Keywords: *Chirostoma*, fishery, aquaculture, Mexico

Introduction

Fisheries and aquaculture activities are fundamental for survival of millions of people around the world, including rural areas anglers who catch fish in lakes and rivers. FAO (2010) ascertains that more than 540 million people perform such activity, which corresponds to 8% of the world population. Mexico is no exception; according to INEGI (2010) reports, there are approximately 300,000 professional of this activity and it is estimate that about 12 million Mexicans are link directly or indirectly to activities within the fisheries sector (Arreguin-Sanchez, 2006).

Economic and cultural aspects are important when fish was capture as income and protein sources. In Mexico, the genus *Chirostoma* is composed of several endemic species of the central plateau, including white fish and the

(✉) monroydosta@hotmail.com

smaller ones called "charales". This fishery is important at national level since it has been the foundation of small-scale fisheries in the central region of the country for centuries; many families depend almost exclusively on the extraction of this kind of fish (Martinez-Palacios *et al*., 2002). However, the fishery is showing a clear decreasing trend: in 1984, a catch of 7,980 tons approximately of fish was report and by 2008, the production decrease to 2,542 tons (SAGARPA, 2003; SAGARPA, 2008). Loss *Chirostoma* production, is mainly due overexploitation versus high demand and economical value (Martinez-Palacios *et al*., 2002; Moncayo *et al*., 2003; Olvera-Blanco *et al*., 2009). Habitat loss and water contamination as a consequence of human population increase settled at lakes and rivers in the Mexican highlands surroundings (Arriaga *et al.,* 2002; Moncayo *et al*., 2003) and the introduction of exotic species that have replaced the native ones (Martinez-Palacios *et al*., 2007; Navarrete-Salgado and Contreras-Rivero, 2011).

One option to reduce the impact on natural populations of white fish in Mexico it is their aquaculture activity (Martinez-Palacios *et al*., 2006). However, the main problem for their production is high mortality in early stages which organisms are reluctant to accept an exogenous diet(Figueroa-Lucero *et al*., 2003; Debnath *et al*., 2007; Gisbert *et al*., 2009; Navarrete and Morales, 2000; Vazquez *et al*., 2013). The conjunction of these problems has caused the extinction of two species of *Chirostoma* and the present status of another four species is currently under risk (NOM-036-PESC-2007).

This paper goal was to inform about the general situation of the species of *Chirostoma* genus in Mexico, providing the available options to improve the condition to diets development for their aquaculture techniques, as well as *in situ* conservation of this ecological resource.

Species of the genus *Chirostoma* and their distribution

The highlands of Central Mexico were the setting of a relatively recent geological process that originated the rugged geography of the Neovolcanic Axis favoring the transformation of the ichthyofauna and generating a new species. Such is the case of the *Chirostoma* genus, represented by 18 species and six subspecies, all natives, which form the freshwater ichthyofauna of Atherinopsidae family in Mexico. This family is branching in two groups: the "charales", of small length (<10 cm) and a range of 6-15 grams weight; and "white fish" (20 cm length) and a range of 200-300 g weight (Rojas-Carrillo and Fernandez-Méndez, 2006.).

Several studies have established the distribution of these fish as follows: in Michoacan at Patzcuaro Lake, the species *C.*

grandocule, *C. attenuatum* and *C. patzcuaro*, as well as a subspecies' of white fish, *Chirostoma estor estor*; at Zirahuen Lake, the charal *C. attenuatum zirahuen* and white fish subspecies' *Chirostoma estor copandaro*, can be found. In Chapala Lake, Jalisco, the species *C. jordani, C. chapalae, C. labarcae, C. arge, C. consocium* and *C. contrerasi* as well as the three white fish species' *Chirostoma lucius, Chirostoma sphyraena* and *Chirostoma promelas* are founding. *Chirostoma humboldtianum*, fourth white fish species' was perhaps the most wide natural distribution specie of this genus, located Zacapu Lake, Michoacán, Lerma River (State of Mexico and Jalisco), Santa Maria and San Pedro lakes at Lagunillas, Nayarit and Juanacatlan, Jalisco (Paulo-Maya *et al*., 2000). Species of *C. jordani* are distributed at Pacific slopes, Mexico Valley at Lerma-Santiago watershed, Ameca River, inner watershed of Mexico Valley and Atotonilco and San Marcos Lakes as well as Atlantic slopes, tributaries of the rivers Pánuco (Tula River), Tecolutla (Necaxa River) and Cazones River (Alvarez del Villar, 1970; Miller *et al*., 2005). In 70's, species of white fish and "charales" were inoculated into water bodies at States of Chihuahua, Puebla, Tamaulipas, Hidalgo, Querétaro, Guanajuato, Mexico State and Michoacan (Rosas, 1976).

Ecological importance

Mexico's fish richness was representing by approximately 2,122 species distributed in 779 genera, 206 families and 41 orders. From this fish richness, an estimate of 384 species inhabits only freshwater environments. However, within this high diversity of species, fish from continental waters are in danger since they were confining in isolated fragments induced by habitat degradation and destruction (De la Vega- Salazar, 2003). Another important aspect was the endemism degree with almost 60% represented by freshwater species.

For Mexican territory, it is estimated that 116 species of sea and freshwater fish are threatened ranging from being vulnerable to critically endangered (www.fishbase.org). The Mexican Official Norm (NOM-059-ECOL-2001) contains a list of 185 species of fish distributed in 64 genera and 32 families including the Atherinopsidae. From the total of species under risk, 40% are under the "threatened" category, 38% as "in danger of extinction", 16% under special protection and 6% likely to be extinct in their natural habitat.

White fish and "charales" fishery

Considering the Mexican fisheries statistics, the capture of Atherinids in Mexican highlands and Mexico Valley lakes represents 8.7% of the national fishing production, with 136,843 metric tons, which generates 513 jobs in shoreline fishery (DOF, 2010). From these jobs, approximately 70% are permanent and the rest were combining with other productive activities (Hernandez, 2006).

In 2007, 22% of the total catches of species of *Chirostoma* genus were from captures of "charal" species and only 1%, from "white fish" (DOF, 2010). In the case of "charal", only 20% was eat fresh along the shoreline and 80% was processed as dry, salted and breaded fried and later distributed at close areas or Mexico City (Hernandez, 2006). With respect "white fish", it was eat 90% in the same region.

Values of "charal" fishery production (2010) for human consumption were showing at Table 1. The Mexican Republic states considered have not seacoast areas. Values are in pesos (Badillo and Gracia, 1995, CONAPESCA, 2010).

Tab. 1: Production values of "charal" fishery for human use in Mexico.

	National production	Total states with no seacoast	Guanajuato	Hidalgo	State of Mexico	Tlaxcala
Total	16, 907, 165	878, 221	29, 116	115, 549	285, 980	11, 134
Direct human use	16, 530, 506	829, 797	29, 116	114, 967	285, 980	10, 898
Charal	27, 871	9, 691	2, 213	44	7, 190	244

Reference: CONAPESCA (2010).

Note: States considered do not have coast shores.

Economic importance

Since prehispanic times, "white fish" and "charales" have importance as a food source since they were highly valued by the cultures that settle at Mexican highlands and Mexico Valley lakes (Hernández, 2006). Recently, these fishes still play an important role as proteins source for many families.

Another important consideration was the income obtained by the exploitation of this natural resource, because this activity sustains many families on the area. Especially if we consider that, these fish can reach a local price up $80.00 US dlls per Kilo (Martinez-Palacios *et al*., 2002).

Current problems

At worldwide level, overexploitation, water pollution, habitat destruction or degradation, sedimentation of water flows and the invasion of exotic species, are aspects that put in risk the freshwater species diversity such as all of these interact in synergy potentiating the negative effects on the species that inhabit these environments (Higgins *et al*., 2005; Dudgeon *et al.,* 2005).

Pollution

In many water bodies of central Mexican highlands, the principal problem is pollution. Mostly, because the anthropic activities such as the discharges from the human settlements, agriculture, livestock and industry as well as the sedimentation leading to the reduction of the lacustrine basins (Saunders *et al.,* 2002) and causing an eutrophication of lakes (Arriaga *et al*., 2002; Olvera-Blanco *et al*., 2009).

Several authors (Arriaga *et al*.,2002; Woodward *et al*.,2012), indicate that Lake Patzcuaro, have a continuous urban discharges contributions which increase the inorganic nitrogen who was associated to agricultural activities and reports concentrations of 0.152 and 2.206 mgL^{-1} at 2000 to 2009 years indicating hypereutrophication condition. This behavior is associated with a high primary production measured as ɑ chlorophyll, which reached an average of 31.8 mgL^{-1} concentration (Sánchez-Chávez *et al*., 2011).

On other hand, tree deforestation generates natural flows of sediments that are incorporated to the lake and modifying the depth of lacustrine basin (Gonzalez *et al*., 2012). Bernal-Brooks *et al*. (2002, 2003) estimated a reduction of 6 m in water depth, affecting directly the species that lives there. Another important aspect was concentrations of fecal coliforms associated to municipal discharges from Patzcuaro, Tzurumutaro and Erongaricuaro localities localized at southern lake area (Sanchez-Chavez *et al*., 2011; Gonzalez *et al*., 2012).

Introduction of exotic species

At worldwide water habitat, there has been a decrease of fish abundance and diversity associated with the increase of exotic species introductions (Helfman, 2007a). Zambrano *et al*. (2011) considered those reckless fish introductions the second most important cause of loss biodiversity. Mexican ichthyofauna does not escape this problem and loss biodiversity is a consequence of interaction between native and introduced species (Miller *et al*., 2005).

For many years ago, mankind has tried to inoculate some fish and crustacean which grow fast and contain nutritional value to obtain better protein resources for people with low food supply and low-income resources (Minns and Cooley, 2000; Canonico *et al*., 2005). Unfortunately, the negative effects of this fish or crustaceans were not considering properly, because the new introduced species caused a displacement of native species and affecting strongly the endemism (Minns and Cooley, 2000). Fishes like example the Nile tilapia, the common carp and the black bass are extremely invasive species and can reduce significantly the *Chirostoma* populations in the Mexican highlands and the lacustrine basins of the Valley of Mexico (CONABIO, 2008). The problem is an interspecific competition to occupy specific feeding niches. In addition, high predation endemic species by introduced fishes has been observing principally with black bass and their analysis of diet composition with white fish and crayfish. The study show that the black bass consumption, increase when they reach the 20 cm length (Toledo-Dias-Rubin, 1995). Due to this, GISD (2005) mentioned that decrease of white fish populations is associated to predation of black bass on their populations.

Overexploitation

In 1980s to 1990s the demand on white fish capture increased considerably and with it, the fishing effort, with a catch of 2,543 tonnes. This related directly to population growth and, as consequence, an increase of the polluting discharges of anthropic origin. These events led to an overload of the traditional fishery and inevitably to overexploitation and failure to comply with federal regulations; in the end this caused a disruption of the relationship between fishermen and the government authorities. To this day, fishermen and authorities sustain a conflict that does not allow for a consensus for the planning and implementation of some strategy to recover the white fish and other native species from the deterioration in which they are now (Vargas, 2011).

In addition, the misuse of the fishing techniques has led to indiscriminate capture of juvenile stage between white fish and the adult stage of "charal", due to difficulty to distinguishing, resulting in the extraction of all stages of both species (Moncayo *et al.,* 2003; Olvera-Blanco *et al*., 2009). Although the identification of these two species using molecular, morphological and meristic traits (Barriga-Sosa, 2001), this knowledge, however, is not useful for fisherman.

Another *Chirostoma* genus problem is the absence of a conservation program to save it and their consequence has been many species of this genus are in risk (NOM-036-PESC-2007). At present time, there are only isolated programs that do not allow an integrated protection and recovery actions. They are only focused on some species and another members of this fishes genus are forgotten (Barriga-Sosa, 2001) and without the habitat pollution condition, the fish diversity of our country was in great danger.

Protection and recovery

In situ conservation

A Mexican government authority's priority must be an adequate management of water bodies, a better efficient legal protection and prevent species loss diversity. For that, it is necessary to perform studies about ecosystems structure and function. Ecological field studies and aquaculture techniques must be conjoin to obtain reproductive biotechnology to make aquaculture pilot projects and inoculations in natural habitats.

Another situation is the absence *in situ* conservation germplasm program, which can give an opportunity to status of *Chirostoma* genus and so successfully deal with future events that are submit (NOM-036-PESC-2007; Barriga-Sosa, 2001).

For the above reasons, *in situ* conservation is not the best available option because the habitat management, habitat disturb and social conflict habitat are not the best situations to allow them as biological “pools” for this purpose.

In Table 2 is show the different studies performed in conservation and aquaculture fields with *Chirostoma* genus. Studies have done in species composition, taxonomic status using classic and molecular techniques, feeding anatomy and digestive physiology.

Tab. 2: Studies on species of the genus *Chirostoma* in Mexico.

Type of study	Author	Title of the publication
Taxonomic	Barbour, 1973	The systematics and evolution of the genus *Chirostoma* Swainson (Pisces, Atherinidae)
	Alaye, 1993	El pescado blanco (género *Chirostoma*) del lago de Pátzcuaro, Michoacán. Composición de Especies
	Alaye, 1996a	Estudio del polimorfismo de la hemoglobina para identificar especies del género *Chirostoma* del lago de Pátzcuaro, Michoacán, México
	Alaye, 1996b	Híbridos entre especies del genero *Chirostoma* del lago de Pátzcuaro, Michoacán, México
	Barriga-Sosa, 2001	Variabilidad morfométrica, merística y molecular de especies del género *Chirostoma* (Pisces: Atherinopsidae)
	Perez, 2003	Discriminación de especies de peces blancos (Atherinopsidae: *Chirostoma*) del lago de Pátzcuaro, por medio de caracteres morfológicos, aloenzimáticos y RFLPs del gen mitocondrial 16S
Biology of the genus	Solorzano, 1963	Algunos aspectos biológicos del pescado blanco del lago de Pátzcuaro (*Chirostoma estor* Jordan, 1897).
	Rosas-Moreno, 1970	Pescado blanco (*Chirostoma estor*) su fomento y cultivo en México
	Rojas *et al*., 2000	Desarrollo y crecimiento de larvas de pescado blanco *Chirostoma estor* Jordan
Feeding behaviour and anatomy	Figueroa-Lucero *et al*., 2004b	Growth, survival and mandible development in the larvae of the shortfin silverside *Chirostoma humboldtianum* (Valenciennes) (Atheriniformes: Atherinopsidae) under laboratory conditions
	Soria y Maya, 2005	Morfometría comparada del aparato mandibular en especies de *Chirostoma* (Atheriniformes: Atherinopsidae) del lago de Pátzcuaro, Michoacán, México
	Martinez-Palacios *et al*., 2006	Aspectos nutricionales del pescado blanco de Pátzcuaro (*Chirostoma estor estor* Jordan, 1879)

Tab. 2: Continued

Type of study	Author	Title of the publication
Feeding behavior and anatomy	Fernandez *et al*., 2008	Alimentación de *Chirostoma humboldtianum* (Valenciennes); (pisces: atherinopsidae) en el estanque JC en Soyaniquilpan, Estado de México
Reproductive biology	Rojas *et al*., 1993	Estimación de los parámetros de crecimiento y ciclo de madurez gonádica del charal blanco *Chirostoma grandocule*, Steindachner, 1894 (Pisces: Atherinidae) del lago de Pátzcuaro, Mich.
	Uria *et al*., 1998	Desarrollo y madurez testicular del charal *Chirostoma humboldtianum* (Pisces: Atherinidae), del embalse Huapango, Edo. De México.
	Ramirez-Sevilla, 2006	Biología reproductiva y ontogenia de *Chirostoma humboldtianum* (Valenciennes, 1835) (Pisces: Atherinopsidae) en condiciones de laboratorio
	Figueroa-Lucero, 2006	Historia de vida reproductiva del charal del Alto Lerma *Chirostoma riojai* Solórzano y López, 1965 (Atheriniformes: Atherinopsidae
	Cardenas *et al*., 2008	Oocyte structure and ultrastructure in the Mexican silverside fish *Chirostoma humboldtianum* (Atheriniforme: Atherinopsidae)
	Blancas-Arroyo *et al*., 2008	Association between ovarian development and serum concentrations of 17β-estradiol and 17α-hydroxy-4-pregnen-3-one in first maturation females of the shortfin silverside fish, *Chirostoma humboldtianum* (Atheriniformes: Atherinopsidae)
	Ibañez *et al*., 2008	Aspectos reproductivos de una población del charal *M. jordani* (Woolman) del lago de Metztitlán, Hidalgo
	Olvera-Blanco *et al*., 2009	Reproductive biology of *Menidia jordani* Atheriniformes: Atherinopsidae) in Xochimilco Lake, Mexico
	Martinez-Palacios *et al*., 2002	Avances en el cultivo del pescado blanco de Pátzcuaro *Chirostoma estor estor*
Pathology	Negrete-Redondo *et al*., Año	Estudio bacteriológico de epizootias causantes de mortalidad masiva en reproductores de pez blanco (*Chirostoma humboldtianum* Valenciennes, 1835), bajo condiciones de cultivo
	Hernandez, 2008	Helmintofauna de *Chirostoma jordani* Woolman, 1894 del lago de Tecocomulco, Hidalgo, México
Nutrition and digestive physiology	Vega *et al*., 2004	Balance energético de juveniles de *Chirostoma estor estor* (Jordan, 1879) (Pisces, Atherinopsidae) en relación con el tamaño corporal.
	Figueroa-Lucero *et al.,* 2004a	Effect of the type of food on the growth and survival of the charal from the high Lerma *Chirostoma riojai* Solórzano y López, 1965 (Atheriniformes: Atherinopsidae) during early development
	Martinez-Palacios *et al*., 2006	Aspectos nutricionales del pescado blanco de Pátzcuaro (*Chirostoma estor estor* Jordan, 1879)
	Hernandez-Martinez *et al.,* 2009	Efecto del alimento vivo enriquecido con *Lactobacillus casei* en la sobrevivencia y crecimiento de larvas y juveniles de *Chirostoma estor* (Pisces: Atherinopsidae)
	Hernandez, 2011	Efecto de *Bifidobacterium animalis* y *Lactobacillus johnsonii* en el crecimiento y sobrevivencia de *Chirostoma jordani* usando metanauplios de *Artemia* sp. como vector

Ex situ actions for conservation

Ex situ actions for conservation refer to all those activities performed to obtain organisms reproduction and maintenance in captivity. Eventually, these organisms can reintroduce successfully to their natural habitat to recover the *Chirostoma* populations (Lacy, 2010; Pizzi *et al*., 2013). A better option can be laboratory, zoo or aquarium culture systems, which can maintain the natural habitat physic chemical conditions for these organisms reproduction (Lascurain *et al*., 2009; IUCN/SSC, 2013).

With this regard, the INAPESCA from Mexico (National Institute of Fisheries) initiated in 2010 a conservation program with *Chirostoma estor*, making experimental culture system studies. Another institution like Michoacana de San Nicolas de Hidalgo University, make studies on culture systems too, but make studies on diets development, feeding anatomy and digestive physiology (Martinez-Palacios *et al*., 2002; Martinez-Palacios *et al*., 2003; Martinez-Palacios *et al*., 2006; Martinez-Palacios *et al*., 2007). The Instituto Politecnico Nacional (IPN) from Mexico make studies on taxonomy, ecology and aquaculture of white fish (Figueroa-Lucero *et al*., 2003) and the Autonoma Metropolitana – Iztapalapa University has focused to studies on culture and technologic transfer production, also taxonomy of the genus (Barriga-Sosa, 2001; Perez, 2003 Blancas-Arroyo *et al*., 2003; PEXPA, 2008).

Currently, none of studies of those academic institutions considered the bioremediation of lake systems and the negative effects evaluations due to introduction of exotic species in those habitats and their low research's application in natural conditions.

Cryopreservation of germplasm as an *ex situ* action for conservation

The second possibility that is offered as an *ex situ* action for the conservation, is germplasm cryopreservation (Lahnsteiner *et al*., 2000; Tsai and Lin, 2012). This methodology allows freezing gametes or reproductive tissue in a controlled way to storing for long periods. This cryopreservation materials can be used in reproduction and restocking programs (Stacey and Day, 2007; Pizzi *et al*., 2013). To make better successful management of this technique, this activity must be associated with habitat bioremediation (IUCN, 2002). Presently, this methodology offers great benefits to aquaculture as well as for gamete conservation of threatened and endangered species (Zhang, 2004; Viveiros y Godinho, 2009; Islam *et al*., 2012; Pizzi *et al*., 2013).

Aquaculture technology

White fish and "charal" aquaculture, either for introduction at natural habitats or commercial production purpose, was already showing positive results reducing wildlife population's impact and generating an income for the local fishermen (Martínez-Palacios *et al*., 2006; Helfman, 2007a). Aquaculture activity is consider the best tool for conservation and sustainable use of commercial species can create directly or indirectly job sources like secondary activities (product distribution, fish marketing, ice production and supply, research and administration, among others). The FAO organization mentioned that these activities were perform for the 10-12% of the world economically active population (FAO, 2012).

Since 70's, altogether with live food production and development of fish aquaculture, the scientific research in laboratories (government and academic institutions), focus their studies to obtain gametes to use it at artificial fecundity and techniques development for better production of larvae and juvenile stages at earth ponds culture (Rosas, 1976). Recently studies were focus to know fish feeding behavior and digestive anatomy of different species of *Chirostoma* genus. Aquaculture techniques are being adapted with respect seasonal food availability or the use of small crustaceans like *Artemia*, *Daphnia* and copepods or insects (larval stages) (Paulo-Maya *et al*., 2000; Blancas-Arroyo *et al*., 2003). White fish adult stage was consider tertiary consumer and they can feed other stages of their same species. Authors as Martinez-Palacios *et al.* (2003), mentioned that this fishes have specialized structures can filtered zooplankton. The common denominator of all scientific researches on white fishes were feeding capacity at first larvae stages to use live food (microalgae, rotifers or *Artemia* nauplii) and changes it later for inert diets to increase growth and reduce mortality (Figueroa-Lucero *et al*., 2004a; Figueroa-Lucero *et al*., 2004b).

The "bottleneck" of white fish aquaculture were the first larval stages survivorship, because the scarce acceptance of inert diets and low nutrient assimilation as well as the mortality stress from handling (Vazquez *et al*., 2013). Considered these three problems, the solution must be the live food production (Lavens and Sorgeloos, 1996) to feed Mexican Atherinopsids. Blancas-Arroyo *et al.* (3003) prove that first larval stages feeding with live food and then mixed with inert diets until changes 100% to exogenous diet given better results. The combination technique with live food and inert diets can be the technology to use at different production laboratories or in earth ponds aquaculture. Another solution can be produce inert diets specifically for white fish and "charal" and stop using trout, tilapia or carp artificial diets, which have different nutritional components very different to nutritional needs for *Chirostoma* genus (Chacon-Torres *et al.,* 2003; Figueroa-Lucero *et al*., 2003; Martinez-Palacios *et al*., 2003). The inert diets to *Chirostoma* genus can be add with benefic substances or microorganisms that increase the enzymatic activity and nutrient assimilation of this fishes in different stages and consequently the survival increase of fish larvae as has happened in other species (Monroy *et al*., 2012).

Helfman (2007a) mentioned that *ex situ* actions maybe was the unique biotechnology for conservation this endemic fishes whose habitat is ecological damage. In this case, the use of aquariums or little ponds is a viable option to do better management and reproductions conditions. For this purpose IUCN (2002), propose several recommendations to those populations that are under risk of extinction (Table 3).

Tab. 3: Expect goals for *ex situ* conservation actions.

✓ Increase public and political awareness, understanding the important conservation issues and significance of extinction.
✓ Genetic and demographic population coordinated management of threatened taxa.
✓ Re-introduction and support to wild populations.
✓ Habitat management.
✓ Restoration.
✓ Long-term gene and biomaterial bank management.
✓ Academic institution strengthening.
✓ Job training capacity.
✓ Sharing appropriated production benefits.
✓ Scientific studies in biological and ecological questions relevant to *in situ* conservation.
✓ Fundraising to support activities.

Note: IUCN (2002).

In conclusion, it is possible to implement programs *in situ* and execute *ex situ* actions for conservation of species of *Chirostoma* genus in Mexico. The conservation activity of these endemic fish can do from two perspectives: a) better fisheries regulation programs with aquaculture pilot projects development and their commercial implementation; and b) bioremediation of natural white fish and "charal" habitats.

Scientific studies did not must go only to molecular taxonomic identification of different species but also in development of first larval stages and the improvement of aquaculture conditions with easily biotechnology transfer to fishermen needs and small producers. Also is important to create a permanent germplasm "stock" in aquariums and gene banks which storing freezing gametes.

References

✓ Alaye R.N. (1993) El pescado blanco (género *Chirostoma*) del lago de Pátzcuaro, Michoacán. Composición de Especies. Ciencia Pesquera. Instituto Nacional de Pesca, México, 9: 113–128.

✓ Alaye R.N. (1996a) Estudio del polimorfismo de la hemoglobina para identificar especies del género

Chirostoma del lago de Pátzcuaro, Michoacán, México. INP. SENARANP. Ciencia Pesquera, 13:1-9.

- ✓ Alaye R.N. (1996b) Híbridos entre especies del género *Chirostoma* del lago de Pátzcuaro, Michoacán, México. Ciencia Pesquera. Instituto Nacional de Pesca. Secretaría del Medio Ambiente Recursos Naturales y Pesca, 13: 10-17.
- ✓ Alvarez del Villar J. (1970) Peces mexicanos (claves). Instituto Nacional de Investigaciones Biológico-Pesqueras. México, Serie Investigaciones Pesqueras, 166 p.
- ✓ Arreguin-Sanchez F.L., Belendez-Moreno I., Mendez Gomez-Humaran M., Solana-Sansores M. and Rangel-Davalos C. (2006) Sustentabilidad y Pesca Responsable en México, Evaluación y Manejo. Instituto Nacional de la Pesca. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México. 544p.
- ✓ Arriaga L., Aguilar V. and Alcocer J. (2002) Lista de las regiones hidrológicas prioritarias; Clave 62: Pátzcuaro y cuencas endorreicas cercanas, en Regiones hidrológicas prioritarias. Aguas continentales y diversidad biológica de México. CONABIO. http://www.conabio.gob.mx/conocimiento/regionalizacion/doctos/hidrologicas.html
- ✓ Badillo J. and Gracia M.L. (1995) Evaluación de la pesquería multiespecífica de charales (*Chirostoma* spp., Pisces, Atherinidae) del Lago de Pátzcuaro, Michoacán, México. Anales del Instituto de Biología. Serie Zoología, 66 (2): 205-231.
- ✓ Barbour C.D. (1973) The systematics and evolution of the genus *Chirostoma* Swainson (Pisces, Atherinidae). Tulane Studies in Zoology and Botany, 18: 97-114.
- ✓ Barriga-Sosa I. de los A. (2001) Variabilidad morfométrica, merística y molecular de especies del género *Chirostoma* (Pisces: Atherinopsidae). PhD Thesis., Universidad Autónoma Metropolitana-Iztapalapa, México, D. F. 199 p.
- ✓ Bernal-Brooks F.W., Gomez-Tagle R.A. and Alcocer J. (2002) Lake Patzcuaro (Mexico): a controversy about the ecosystem water regime approached by field references, climatic variables, and GIS. Hydrobiologia, 467: 187-197.
- ✓ Bernal-Brooks F.W., Davalos-Lind L. and Lind O.T. (2003) Seasonal and spatial variation in algal growth potential and growth-limiting nutrients in a shallow endorheic lake. Lake Pátzcuaro (México). Lakes & Reservoirs: Research and Management, 8: 83 – 93.
- ✓ Blancas-Arroyo A.G., Figueroa-Lucero G., Barriga-Sosa I de los A. and Arredondo-Figueroa J.L. (2003) Aportaciones al cultivo controlado del pez blanco, *Chirostoma humboldtianum*, Valenciennes, 1835 (Pisces: Atherinopsidae). In: Rojas C. P. M. and Fuentes C. D. (Eds.). Historia y avances del cultivo de Pescado blanco*.* Instituto Nacional de la Pesca, SAGARPA, México, D.F.:155-168.
- ✓ Blancas-Arroyo G.A., Barriga-Sosa I de los A., Morato-Cartagena T., Romero-Ramírez C.M. and Arredondo-Figueroa J. L. (2008) Association between ovarian development and serum concentrations of 17β-estradiol and 17α-hydroxy-4-pregnen-3-one in fi rst maturation females of the shortfin silverside fish, *Chirostoma humboldtianum* (Atheriniformes: Atherinopsidae). Revista Veterinaria México, 39: 67-80.
- ✓ Canonico C.G., Arthington A., McCrary J.K. and Thieme M.L. (2005) The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems, 15(5): 463–483.
- ✓ Cardenas R., Chávez M., Gonzalez J.L., Aley P., Espinosa J., and Jimenez-Garcia L.F. (2008) Oocyte structure and ultrastructure in the Mexican silverside fish *Chirostoma humboldtianum* (Atheriniforme: Atherinopsidae) Revista de Biología Tropical, 56: 1371-1380.
- ✓ Chacón-Torres A., Rosas-Monge C. and Segura-García V. (2003) Biología reproductiva y alimentación larvaria del pez blanco en condiciones experimentales. In: Rojas C. P. M. and Fuentes C. D. (Eds.). Historia y avances del cultivo de Pescado blanco*.* Instituto Nacional de la Pesca, SAGARPA, México, D.F.:125-139 p.
- ✓ CONABIO (2008) Sistema de información sobre especies invasoras en México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Date of reference: 18th October 2013. Last actualization: 5th January 2011. http://www.conabio.gob.mx/invasoras
- ✓ CONAPESCA (2010) Anuario estadístico de acuicultura y

pesca 2010.SAGARPA-CONAPESCA. México, D.F.:296 p.

- Debnath D., Pal A.K., Sahu N.P., Yengkokpam S., Baruah K., Choudhury D. and Venkateshwarlu G. (2007) Digestive enzymes and metabolic profile of *Labeo rohita* fingerlings fed diets with different crude protein levels. Comparative Biochemistry and Physiology, Part B, 146: 107–114.
- De la Vega-Salazar M.Y. (2006) Estado de conservación de los peces de la familia Goodeidae (Cyprinodontiformes) en la mesa central de México. Rev. Biol. Trop., 54: 163-171.
- DOF. Diario Oficial de la Federación (2010) Acuerdo mediante el cual se da a conocer la actualización de la Carta Nacional Pesquera. Segunda Sección, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México, D. F.
- Dudgeon D., Arthington H.A., Gessner M.O., Zen-Ichiro K., Knowler D.J., Léveque C., Naiman R.J., Prieur-Richard A-H., Soto D., Stiassny M.L.J. and Sullivan C.A. (2005) Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews, 81: 163-182.
- FAO. Organización de las Naciones Unidas para la Agricultura y la Alimentación. (2010) El estado mundial de la Pesca y la Acuicultura. Roma, Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). Roma, Italia. 218p.
- FAO. Organización de las Naciones Unidas para la Agricultura y la Alimentación. (2012) Examen mundial de la pesca y la acuicultura. Situación y tendencias. In: Estado mundial de la pesca y la acuicultura 2012. Departamento de Pesca y Acuicultura de la FAO. Roma, Italia. 3-22.
- Fernández G.E., Navarrete S.N.A. and Rodríguez R.J.L. (2008) Alimentación de *Chirostoma humboldtianum* (valenciennes); (pisces:atherinopsidae) en el estanque JC en Soyaniquilpan, Estado de México. Revista Chapingo Serie Ciencias Forestales y del Ambiente, 14: 129-134.
- Figueroa-Lucero G., Paulo-Maya J. and Hernández-Rubio Ma. C. (2003) Retrospectiva y avances en el conocimiento de la biología y ecología de los charales y peces blancos del género *Chirostoma* (Atheriniformes: Atherinopsidae) en la ENCB-IPN. In: Rojas C. P. M. and Fuentes C. D. (Eds.). Historia y avances del cultivo de Pescado blanco*.* Instituto Nacional de la Pesca, SAGARPA, México, D.F.:29-48.
- Figueroa-Lucero G., Ma. Hernández- Rubio C., Meza-González O., Arredondo-Figueroa J.L., Castro-Barreda T. and Barriga-Sosa I.de los A. (2004a) Effect of the type of food on the growth and survival of the charal from the high Lerma *Chirostoma riojai* Solórzano y López, 1965 (Atheriniformes: Atherinopsidae) during early development. Journal of Biological Research, 2: 93-99.
- Figueroa-Lucero G., Meza-González O., Cecilia Hernández-Rubio M., Barriga-Sosa I. de los A., Rodríguez-Canto A. and Arredondo-Figueroa J.L. (2004b) Growth, survival and mandible development in the larvae of the shortfin silverside *Chirostoma humboldtianum* (Valenciennes) (Atheriniformes: Atherinopsidae) under laboratory conditions. Aquaculture, 242: 689–696.
- Figueroa-Lucero G. (2006) Historia de vida reproductiva del charal del Alto Lerma *Chirostoma riojai* Solórzano y López, 1965 (Atheriniformes: Atherinopsidae). PhD Thesis, Universidad Autónoma Metropolitana unidad Iztapalapa. 175 p.
- Gisbert E., Giménez G., Fernández I., Kotzamanis Y. and Estévez A. (2009) Development of digestive enzymes in common dentex Dentex dentex during early ontogeny. Aquaculture, 287: 381–387.
- Global Invasive Species Database (GISD) (2005) *Micropterus salmoides*. http://www.issg.org/database/species/ecology.asp?si=19&fr=1& sts=sss
- González V.R., Sánchez C.J.J., Bravo I.L.A., Tomasini O.A.C., Sánchez C.L., Córdova R.M.A., and García V. N. H. (2012) Cambio climático en la calidad del agua del lago de Pátzcuaro. XXII Congreso Nacional de Hidráulica, Acapulco, Guerrero, México.
- Helfman G.S. (2007a) Habitat modification and loss. In: Fish Conservation, A guide to understanding and restoring global aquatic biodiversity and fishery resources. Island Press, Washington. 97-129.
- Helfman G.S. (2007b) The promise of aquaculture and

hatcheries. In: Fish Conservation, A guide to understanding and restoring global aquatic biodiversity and fishery resources. Island Press, Washington. 407-437.

- ✓ Hernández M.D. (2006) La pesquería en el lago de Pátzcuaro. In: Arreguín S.F., Beléndez M.L., Gómez-Humaran M.I., Solana S.R. and Rangel D.C. (eds.), Sustentabilidad y pesca responsable en México. Evaluación y manejo. Instituto Nacional de la Pesca. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México, D. F. 391-422.
- ✓ Hernández B.A.F. (2011) Efecto de *Bifidobacterium animalis* y *Lactobacillus johnsonii* en el crecimiento y sobrevivencia de *Chirostoma jordani* usando metanauplios de *Artemia* sp. como vector. Informe Final de Servicio Social. Universidad Autónoma Metropolitana unidad Xochimilco, México Distrito Federal. 39 p.
- ✓ Hernández H.D.L. (2008) Helmintofauna de *Chirostoma jordani* Woolman, 1894 del lago de Tecocomulco, Hidalgo, México. Tesis, Universidad Autónoma del Estado De Hidalgo, Hidalgo, México. 77 p.
- ✓ Hernández-Martínez M., Castro-Barrera T., Garduño-Dionate M., Castro-Mejía G. and Baltierra-Rodríguez J.l. (2009) Efecto del alimento vivo enriquecido con *Lactobacillus casei* en la sobrevivencia y crecimiento de larvas y juveniles de *Chirostoma estor* (Pisces: Atherinopsidae). Ciencia Pesquera, 17: 5-12.
- ✓ Higgins V.J., Bryer T.M., Khoury L.M. and Fitzhugh W.T. (2005) A freshwater classification approach for biodiversity conservatio planning. Conservation Biology, 19: 432-445.
- ✓ Ibáñez A.L., García-Calderón J.L. and Torres-Orozco R.B. (2008) Aspectos reproductivos de una población del charal *M. jordani* (Woolman) del lago de Metztitlán, Hidalgo. Hidrobiológica, 18: 1-9.
- ✓ INEGI. Instituto Nacional de Estadística y Geografia. (2010) El sector alimentario en México. Serie Estadísticas sectoriales. México D.F.298p.
- ✓ Islam S.M.R., Monowar S.M.F. and Saha S.K. (2012) Cryopreservation of sperm of an indigenous endangered fish species *Nandus nandus* (Hamilton, 1822) for ex-situ conservation. Cryobiology, 65: 202-209.
- ✓ IUCN (2002) Technical guidelines on the management of *ex-situ* populations for conservation. Gland, Switzerland. Date of reference: 19th September 2013. http://data.iucn.org/dbtw-wpd/edocs/Rep-2002-017.pdf
- ✓ IUCN/SSC (2013) Guidelines for reintroductions and other conservation translocations. Versión 1.0. Gland, Switzerland: IUCN Species Survival Commission, VIIII + 57 pp. http://www.cbsg.org/integrated-datamanage me nt-reintroductions-and-translocations
- ✓ Lacy R.C. (2011) Re-thinking *ex situ* vs. *in situ* species conservation. In: G. Dick, (ed.) Biodiversity is Life. Proceedings of the 65th Annual Conference of the World Association of Zoos and Aquariums. WAZA, Gland, Switzerland. 25-29.
- ✓ Lahnsteiner F., Berger B.A., Horvath A., Urbanyi B. and Weismann T. (2000) Cryopreservation of spermatozoa ln cyprinid fishes. Theriogenology, 54: 1477-1496.
- ✓ Lascuráin M., List R., Barraza L., Díaz P. E., Gual S. F., Maunder M., Dorantes J. and Luna V.E. (2009) Conservación de especies *ex situ*, en Capital natural de México, vol. II: Estado de conservación y tendencias de cambio. CONABIO, México. 517-544.
- ✓ Lavens P. and Sorgeloos P. (1996) Introduction.: Lavens P. y Sorgeloos P. (eds.), Manual on the Production and Use of Live Food for Aquaculture. FAO, Fisheries Technical Paper. No. 361. Rome, Italy. 1-6. In
- ✓ Martínez-Palacios C.A., Ríos-Durán Ma. G., Campos-Mendoza A., Toledo-Cuevas M. and Ross L.G. (2002) Avances en el cultivo del pescado blanco de Pátzcuaro *Chirostoma estor estor*. In: Cruz-Suárez L. E., Ricque-Marie D., Tapia-Salazar M., Gaxiola-Cortés M. G. y Simoes N. (Eds.). Avances en Nutrición Acuícola VI. Memorias del VI Simposium Internacional de Nutrición Acuícola. 3 to 6 September 2002. Cancún, Quintana Roo, México.
- ✓ Martínez Palacios C.A., Ríos-Durán Ma.G., Campos-Mendoza A., Toledo-Cuevas E.M., Aguilar-Valdéz Ma.delC. and Ross L.G. (2003) Desarrollo tecnológico alcanzado en el cultivo del pez blanco de Pátzcuaro. In: Rojas C. P. M. y Fuentes C. D. (Eds.). Historia y avances

del cultivo de Pescado blanco. Instituto Nacional de la Pesca, SAGARPA, México, D.F. 169-189.

- Martínez-Palacios C.A., Toledo-Cuevas M., Racotta-Dimitrov E., Ríos-Durán Ma. G., Palacios-Metchenov E., Fonseca-Madrigal J., Campos-Mendoza A. and Ross L.G. (2006) Aspectos nutricionales del pescado blanco de Pátzcuaro (*Chirostoma estor* estor Jordan, 1879). In: L. Elizabeth Cruz Suárez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto López, David A. Villarreal Cavazos, Ana C. Puello Cruz and Armando García Ortega (Eds.). Avances en Nutrición Acuícola VIII. VIII Simposium Internacional de Nutrición Acuícola. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694-333-5.
- Martínez-Palacios C.A., Ríos-Durán M.G., Ambriz-Cervantes L., Jauncey K.J. and Ross L.G. (2007) Dietary protein requirement of juvenile Mexican Silverside *Menidia estor* Jordan 1879), a stomachless zooplanktophagous fish. Aquaculture Nutrition, 13: 304–310.
- Miller R.R., Minckley W.L. and Norris S.M. (2005) Freshwater fishes of México. The University of Chicago Press, Chicago, USA. 490 p.
- Minns K.C. and Cooley M J. (2000) Intentional introduction: Are the incalculable risks worth it?. In: Claudi R. y Leach H. J. (eds.), Nonindigenous freshwater organisms, vectors, biology, and impacts. Lewis Publishers, Washintong. 57-59.
- Moncayo E.R., Escalera G.C. and Segura G.V. (2003) Los pescados blancos del lago de Chapala características generales, en Historia y Avances del Cultivo del Pescado Blanco, Instituto Nacional de Pesca, Dirección General de Investigación en Acuacultura, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México, D. F. 51-77.
- Monroy D.M.C., Castro B.T., Castro M.J. Castro M.G. and De Lara A. (2012) Beneficio del uso de probióticos en la flora bacteriana de organismos acuáticos. Revista Contactos, 85: 11-18.
- Navarrete S.N. and Morales V.J. (2000) Transporte de *Chirostoma humboldtianum* en bolsas de plástico. Revista de zoología, 011: 12-15.
- Navarrete-Salgado N.A. and Contreras-Rivero G. 2011.Crecimiento y mortalidad del charal (*menidia jordani*) en el estanque Guillermo Lagunes (gl), Estado de México. Revista Chapingo. Serie Ciencias Forestales y del Ambiente, 17: 407-410.
- Norma oficial mexicana NOM-059-ECOL-2001, Protección ambiental-especies nativas de México de flora y fauna silvestres-categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-lista de especies en riesgo. Diario Oficial de la Federación, México Distrito Federal.
- Norma Oficial Mexicana NOM-036-pesc-2007, Pesca responsable en el lago de Pátzcuaro ubicado en el estado de Michoacán. Especificaciones para el aprovechamiento de los recursos pesqueros. Diario oficial de la federación, México Distrito Federal.
- Olvera-Blanco Y.M., Gómez-Márquez J.L., Peña-Mendoza B., Gaspar-Dillanes Ma.T. and Pérez C. (2009) Reproductive biology of *Menidia jordani* Atheriniformes: Atherinopsidae) in Xochimilco Lake, Mexico. Ciencia Pesquera, 17: 65-75.
- Paulo-Maya J., Figueroa L.G. and Soria-Barreto M. (2000) Peces dulceacuícolas mexicanos XIX *Chirostoma humboldtianum* Atheriniformes: Atherinopsidae*).* ENCB-IPN, Zoología Informa, 43: 59-74.
- Pérez R.M.Y. (2003) Discriminación de especies de peces blancos (Atherinopsidae: *Chirostoma*) del lago de patzcuaro, por medio de caracteres morfológicos, aloenzimóticos y RFLPs del gen mitocondrial 16S. Thesis, Universidad Autónoma Metropolitana-Iztapalapa. México, D. F. 40 p.
- Pizzi F., Caroli A.Ma., Landini M., Galluccio N., Mezzelani A. and Milanesi L. (2013) Conservation of endangered animals: From biotechnologies to digital preservation. Natural Science, 5: 903-913.
- Programa Experimental de Producción Acuícola (PEXPA) (2008) Rescate y cultivo de las especies nativas de la Cuenca de México. Universidad Autónoma Metropolitana-Iztapalapa. http://www.izt.uam.mx/pexpa/paginablanco/Index.htm
- Ramírez-Sevilla R. (2006) Biología reproductiva y

ontogenia de *Chirostoma humboldtianum* (Valenciennes, 1835) (Pisces: Atherinopsidae) en condiciones de laboratorio. Doctorado en Ecología, Secretaría de Investigación y Posgrado, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional. 155 p.

- Rojas C.P, Jiménez B.M., Toledo D.Ma.deL., and Mares B.L. (1993) Estimación de los parámetros de crecimiento y ciclo de madurez gonádica del charal blanco *Chirostoma grandocule*, Steindachner, 1894 (Pisces: Atherinidae) del lago de Pátzcuaro, Mich. Ciencia Pesquera, 69–77.
- Rojas C.P.M., Mares B. L. G., Morales P. J. J., Sabanero M. S., Hernández Z. N., León M. G. and León J. F. (2000) Desarrollo y crecimiento de larvas de pescado blanco *Chirostoma estor* Jordan. Informe Final de Investigación. Proyecto CONACYT-Instituto Nacional de la Pesca. No. Ref. 1185P-B9507.
- Rojas-Carrillo P.M. and Fernández-Méndez J.I. (2006) La pesca en aguas continentales. In: Pesca, Acuicultura e Investigación en México. Comisión de Pesca, Cámara de Diputados, México. 49-68.
- Rosas M. M. (1976) Datos biológicos de la ictiofauna del lago de Pátzcuaro con especial énfasis en la alimentación de sus especies. Memorias del Simposio de pesquerías en aguas continentales. 3-5 noviembre 1976. Tuxtla Gutiérrez, Chis. Instituto Nacional de la Pesca. Tomo II. 299-366.
- Rosas-Moreno, M. (1970) Pescado blanco (*Chirostoma estor*) su fomento y cultivo en México. SIC. Instituto Nacional de Investigaciones Biológico Pesqueras. Instructivo 2. Serie Divulgación. Comisión Nacional Consultiva de Pesca. Dirección General de Pesca e Industrias Conexas. 79 p.
- SAGARPA. (2003) Anuario estadístico de pesca 2003. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México. http://www .sagarpa.gob.mx.
- SAGARPA. (2008) Programa Rector Nacional de Pesca y Acuacultura Gobierno de México, Poder Ejecutivo Federal. Sosa, F., Colín, A., Torres, L.M., Hernández, M. 2000. Trucha. Cap. IX. In: Álvarez-Torres, M. Ramírez-Flores, L.M. Torres-Rodríguez y A. Díaz de León-Corral (Eds). Estado de Salud de la Acuacultura, 2000. INP.
- Sánchez-Chávez J., Bravo-Inclán L., Tomasini-Ortiz C. and Bernal-Brooks F. (2011) Calidad del agua del lago de Pátzcuaro. In: Huerto D. R., Vargas V. S. y Ortiz P. C. (eds.) Estudio ecosistémico del lago de Pátzcuaro: aportes en gestión ambiental para el fomento del desarrollo sustentable. Instituto Mexicano de Tecnología del Agua, Jiutepec, Morelos, México. 27-46.
- Saunders D.L., Meeuwig J.J. and Vincent A.C.J. (2002) Freshwater Protected Areas: Strategies for Conservation. Conservation Biology, 16: 30–41.
- Solórzano P.A. (1963) Algunos aspectos biológicos del pescado blanco del lago de Pátzcuaro (*Chirostoma estor* Jordan, 1879). SIC. Dirección General de Pesca e Industrias Conexas. Instituto Nacional de Investigaciones Biológico Pesqueras. 1-15.
- Soria B.M. and Maya J.P. (2005) Morfometría comparada del aparato mandibular en especies de *Chirostoma* (Atheriniformes: Atherinopsidae) del lago de Pátzcuaro, Michoacán, México. *Hidrobiológica,* 15: 161-168.
- Stacey N. and Day G.J. (2007) Long-term *ex situ* conservation of biological resources and the role of biological resource centers. In: Stacey N. G. and Day G. J. (eds.) Cryopreservation and freeze-drying protocols. Humana Press, Nueva Jersey. 1-14.
- Tsai S. and Lin C. (2012) Advantages and applications of cryopreservation in Fisheries science. Brazilian Archives of Biology and Technology, 55: 425-433.
- Toledo-Díaz-Rubín M.P. (1995) Consumo de aterínidos (*Chirostoma* sp.) por la lobina negra (*Micropterus salmoides*) en el lago de Pátzcuaro, Mich., México, en 1986. INP-SEMARNAP. Ciencia Pesquera, 11: 71-74.
- Uria G.E., Moncayo L. Ma. E. and Garibay G.R. (1998) Desarrollo y madurez testicular del charal *Chirostoma humboldtianum* (pisces: atherinidae), del embalse Huapango, Edo. De México. Hidrobiológica, 8: 9-18.
- Vargas V.S. (2011) Los pescadores del lago; entre el manejo comunitario y el deterioro ambiental. In: Huerto D.R., Vargas V.S. and Ortiz P.C. (eds.) Estudio ecosistémico del lago de Pátzcuaro: aportes en gestión

ambiental para el fomento del desarrollo sustentable. Instituto Mexicano de Tecnología del Agua, Jiutepec, Morelos, México. 189-216.

- Vázquez G., Castro T., Hernández A., Castro J. and De Lara R. (2013) Comparación del efecto anestésico del aceite de clavo, solución salina y solución coloidal en juveniles de *Chirostoma jordani* (Woolman, 1894). Archivos de Medicina Veterinaria, 45: 59-66.
- Vega Ma.V., Díaz F. and Espina S. (2004) Balance energético de juveniles de *Chirostoma estor estor* (Jordan, 1879) (Pisces,Atherinopsidae) en relación con el tamaño corporal. Hidrobiológica, 14: 113-120.
- Viveiros A.T.M. and Godinho H.P. (2009) Sperm quality and cryopreservation of Brazilian freshwater fish species: a review. Fish Physiology and Biochemistry, 35: 137-150.
- Woodward C.A., Potito A.P. and Beilman D.W. (2012) Carbon and nitrogen stable isotope ratios in surface sediments from lakes of western Ireland: implications for inferring past lake productivity and nitrogen loading. Journal of Paleolimnology, 47: 167-184.
- Zambrano L., Cordova T.F., Ramírez H.J.P., Mar S.V., Bustamante L., Camargo T. and Bustamante E. (2011) Las especies exóticas en el lago de Pátzcuaro, Michoacán, México. In: Huerto D.R., Vargas V. S. and Ortiz P.C. (eds.) Estudio ecosistémico del lago de Pátzcuaro: aportes en gestión ambiental para el fomento del desarrollo sustentable. Instituto Mexicano de Tecnología del Agua, Jiutepec, Morelos, México. 131-154.
- Zhang T. (2004) Cryopreservation of gametes and embryos of aquatic speceies. In: Fuller J. B., Lane N. y Benson E. E. (eds.) Life in the frozen state. CRC Press, Washintong.425-436.