Conservation Status of the "Piracanjuba" Brycon orbignyanus (Valenciennes, 1850) (Characiformes, Bryconidae): Basis for Management Programs

Daniela José de Oliveira[1], Fernando Yuldi Ashikaga[1], Fausto Foresti[1] & José Augusto Senhorini[2]

Recebido em 28/05/2015 – Aceito em 07/04/2016

RESUMO – A exploração excessiva dos recursos de água doce tem causado muitos impactos sobre as populações naturais, especialmente em peixes. Diferentes fatores relacionados com a poluição, sobrepesca, introdução de espécies exóticas, construção de barragens e destruição de vegetação ripárias podem determinar mudanças nas populações atuais e interferir em seu equilíbrio. Neste contexto, *Brycon orbignyanus*, popularmente conhecido como "piracanjuba", é uma espécie de peixe ameaçada de extinção pela pesca excessiva e degradação do meio ambiente. A qualidade da carne e do seu comportamento agressivo na prática da pesca desportiva e profissional, ocorrendo concomitantemente às mudanças contínuas no habitat, resultaram no esgotamento rápido dos estoques naturais e determinaram sua entrada na lista de espécies de peixes brasileiros ameaçados de extinção. A espécie tem distribuição ao longo da bacia do Rio da Prata em áreas altamente impactadas pela ocupação demográfica, construção de barragens e atividades agrícolas em áreas marginais. Populações nativas desta espécie ocupam regiões menos afetadas, sendo atualmente restrita a poucos rios distantes de centros urbanos e pequenos afluentes onde as condições ambientais permanecem preservadas. Com o objetivo de verificar o estado de conservação das populações de *B. orbignyanus*, visando o desenvolvimento de programas de gestão eficazes para a conservação da espécie, o artigo reúne informações disponíveis na literatura e fornecer informações biológicas da espécie sobre a sua real distribuição geográfica, principais ameaças, características genéticas de populações e as perspectivas para o uso em programas de conservação.

Palavras-chave: Peixe ameaçado; estado de conservação; recomendações de manejo.

ABSTRACT – The excessive exploitation of freshwater resources has been caused by many impacts on natural populations, especially on fish. Different factors related to pollution, overfishing, introduction of exotic species, construction of dams, and destruction of riparian vegetation can cause changes on the current

Afiliação

[1] Laboratório de Biologia e Genética de Peixes (LBGP), Departamento de Morfologia, Instituto de Biociências, Universidade Estadual Paulista, Distrito de Rubião Junior, s/n, Botucatu/SP, Brasil. CEP: 18618-970.

[2] Centro Nacional de Pesquisa e Conservação da Biodiversidade Aquática Continental (CEPTA)/Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Rodovia SP-201 (Pref. Euberto Nemésio Pereira de Godoy), Km 6,5, Pirassununga/SP, Brasil. Caixa Postal 64, CEP: 13.630-970.

E-mails

daniela.jo@outlook.com, fyuldi@gmail.com, fforesti@unesp.br, jose.senhorini@icmbio.gov.br

populations and interfere with their equilibrium. In this context, *Brycon orbignyanus*, popularly known as "piracanjuba", is an endangered fish species affected by overfishing and environmental degradation. The quality of the meat and its aggressive behavior in the practice of sport and professional fishing, occurring concomitantly to continuous changes in the habitat, has resulted in the fast depletion of natural stocks and resulted in its addition to the list of endangered Brazilian fish species. The species has its distribution along the La Plata River basin, which has in its upper parts highly impacted by demographic occupation, dam constructions, and agricultural farm activities in marginal areas. Habitat changes lead the wild groups of this species to shift to less affected regions, being presently restricted to a few far rivers and small tributaries that remain in preserved environmental conditions. In order to obtain a better view of the real situation of *B. orbignyanus* populations, the aim of this work is the development of effective management programs for the conservation of this species. The article brings together information available in the literature and provides biological and population information about its current geographic distribution, the main threats to the equilibrium in the changing environments of occurrence, the genetic characteristics of populations, and the prospects for use in conservation programs.

Keywords: Endangered fish; conservation state; management recommendations.

RESUMEN – La sobreexplotación de los recursos en agua dulce ha causado grandes impactos sobre las poblaciones naturales, especialmente en los peces. Diferentes factores relacionados con la contaminación, sobrepesca, introducción de especies exóticas, construcción de presas y la destrucción de los bosques ribereños pueden determinar cambios en las poblaciones actuales e interferir con el equilibrio. En este contexto, *Brycon orbignyanus*, popularmente conocido como "piracanjuba", es una especie de peces en peligro de extinción debido ala pesca excesiva y la degradación del medio ambiente. La calidad de la carne y su comportamiento agresivo en la pesca profesional y deportiva, que se producen de forma concomitante con los continuos cambios en el hábitat, resultadon en rápido agotamiento de las reservas naturales y determinaron su entrada en la lista brasileña de espécies de peces en peligro de extinción. Esta espécie se distribuye a lo largo de la cuenca del Río de la Plata en áreas altamente afectadas por la ocupación demográfica, construcción de presas atividades agricolas en áreas marginales. población nativa de esta especie ocupan regiones menos afectadas, las cuales se restringen a algunos afluentes distantes de centros urbanos siendo preservadas sus condiciones ambientales. Con el fin de comprobar el estado de las poblaciones de *B. orbignyanus*, para desarrollar programas de gestión eficaces para su conservación el presente artículo compila información disponible en literatura de igual manera proporciona información de la biologia de la espécie sudistribución geográfica real, principales amenazas, las características genéticas de las poblaciones y perspectivas para su uso en los programas de conservación.

Palabras clave: Pescado amenazado; estado de conservación; recomendaciones de manejo.

Introduction

The direct exploitation of natural animal populations for large-scale consumption, as presently occurs with fish, is a problem and requires specifically different solutions from those arising from the exploitation of domesticated plants and animals (Solé-Cava 2001). Per FAO (2016), about 93 million tons of fish were taken directly from natural seas and freshwater populations around the world in 2014, while only 73 million tons came from aquaculture. These data point to the fact that natural fish stocks have suffered a significant impact, which certainly caused a reduction of individuals in waterways as the result of uncontrolled exploitation of resources, capture of juveniles, overfishing, and lack of supervision and protectionist measures (Agostinho & Gomes 2005). Besides fishing, other factors can further the risk of fish species extinction in freshwater waters, such as the increasing fragmentation of rivers by dam construction, which modifies the collective spawning areas and disrupts the reproductive migration route of some species; the introduction of exotic species; the riparian deforestation and water pollution; amongst other (Frankham *et al*. 2002, Agostinho & Gomes 2005, Frankham 2005).

Several measures have been taken to prevent the extinction of species, like the recommendation from the Instituto Brasileiro de Recursos Naturais (IBAMA) IN nº 146/07 (Brasil, 2007), which establishes that any entity that impacts the environment should take measures to protect biological resources. However, many actions that seek to conserve such resources have been taken without strong scientific basis, thus resulting in less application and effectiveness, as related by Agostinho *et al*. (2005). A clear example of an ineffective implementation of the measure is revealed in traditional restocking programs undertaken by various entities, which neglect basic biological features of the species, and are questioned for their efficiency and negative impact on natural fish populations (Agostinho *et al*. 2002).

Among the 3130 species of freshwater fish known to habitat Brazil (Reis *et al*. 2016), 312 are found on the official list of endangered species IN 445/2014, including *Brycon orbignyanus* "piracanjuba" (Brasil, 2014). It is a rheophilic and omnivorous fish species, whose diet includes a preference for fruits and seeds (Eckmann 1984). The habitat of this species is throughout the La Plata River basin, being very sought after by humans due to the quality and acceptance of their meat, as well as for their aggressive behavior during sport fishing (Lima *et al*. 2003).These reasons can explain why the species has been massively exploited in addition to other factors already mentioned, and as a result, the remaining native populations are becoming drastically reduced, being currently listed in the "Red Book of Endangered Fauna" (Oyakawa *et al*. 2009, Brasil 2014).

Thus, understanding the biology and population dynamics of the species must be emphasized to implement the application of effective measures to preserve fish stocks (Agostinho & Gomes 1997, Hahn *et al*. 1998, Agostinho *et al*. 2002, Hilsdorf & Petrere 2002, Rocha *et al*. 2005, Ribeiro-Filho *et al*. 2011). Therefore, the aim of this review is to present basic information about *Brycon orbignyanus*, the current conservation status of wildlife populations, and conservation measures that could be employed to preserve natural stocks of the species. Thus, it can be expected that the information presented can contribute to the development of effective management plans for this species.

Taxonomy, Morphology, Behavior, and Food Habit of Species

The species *Brycon orbignyanus* (Valenciennes 1850) is described taxonomically within the Osteichthyes class, Actinopterigii subclass, Teleostei infraclass, Ostariophysi superorder, Characiformes order, Briconidae Family, Bryconinae subfamily and *Brycon genus* (Lauder & Lien 1983, Britski *et al*. 1988, Oliveira *et al*. 2011, Abe *et al*. 2014).

Brycon orbignyanus (Valenciennes 1850), the fish known as "piracanjuba, bracanjuva, piracanjuva", comprises a group of species that can reach a large body size in addition to enlarged heads and body features composed of two large fontanels (Godoy 1975). The individuals are very similar in external morphology when compared each other (Figure 1), having a rounded abdomen that makes the body fusiform, especially in young specimens. The maxilla and dentary have, in most cases, the same length, but the jaw may sometimes be slightly shorter than the maxilla (Godoy 1975). Below the buccal mucosa, it is possible to observe the presence of teeth with five cusps, arranged in three series in the premaxilla, one in the maxilla (Godoy 1975), and another inner series with two conical teeth situated near the symphysis (Godoy 1975). The species presents numerous gill-rakers, which are on the gill arches (Godoy 1975). The middle rays of the caudal fin are slightly longer, forming a marginal edge. The specimens are of orange color and present a red tail with a black band beginning on the caudal peduncle (Godoy 1975, Vaz *et al*. 2000).

Figure 1 – *Brycon orbignyanus* (Valenciennes, 1850), 33 cm SL.

The "piracanjuba" is a species that performs trophic and reproductive migrations (Lima *et al*. 2003). Its omnivorous habit, being of preference for fruits and seeds during the period of floods and crustaceans and small fish during periods of drought, gives the species enormous capacity for digestion and assimilation of proteins of plant origin (Ceccarelli *et al*. 2005). Due to the great capacity of migration, *B. orbignyanus* lives preferably in stretches with continuous water flow, being characterized as a rheophilic species (Lima *et al*. 2003). The reproductive migration generally occurs during the flooding river station in the period from September until January (Godoy 1975).

During the reproduction stage, females have a gonadal development increase between 12-20% of total weight of the fish (Zaniboni-Filho & Schulz 2003). In the natural environment, males are usually ready to perform spermiation at two years old when they reach approximately 20 inches in length, being characterized by a sexual dimorphism in the anal fin that has a rough texture (Ceccarelli *et al*. 2005). Females, in turn, reach sexual maturity later, approximately at three years old and being 25 inches long. The spawning is complete with the total emptying of gonadal contents (Ceccarelli *et al*. 2005). The process of fertilization is external without parental care; the eggs present a semi-dense appearance and larvae have carnivorous habits initially (Zaniboni-Filho & Schulz 2003).

The distribution of populations

The River de La Prata basin is formed by three major hydrographic systems composed of the Paraná River, the Paraguay River, and the Uruguay River, covering an area of influence of five countries including Brazil, Uruguay, Bolivia, Paraguay, and Argentina (Figure 2) (Reis *et al*. 2003). A broad record of occurrences is registered for the species *B. orbignyanus*, mainly in the Paraná and Uruguay rivers and their tributaries that are found in areas of the Atlantic Forest and Cerrado, especially in Tropical regions (Cavalcanti 1998, Reis *et al*. 2003).

The current distribution and occurrence of *B. orbignyanus* is quite different from that existing a few decades ago, knowing that this species constituted one of the main products in fisheries with a register of capture that reached five tons per year in the Mogi Guaçu River in the 1940s (Figure 2) (Schubart 1943). In this area, the presence of the species was monitored until 2009 when just one specimen was registered in this river. In the Uruguay River and its tributaries where this species was also once abundant, its capture is a rare occurrence now, being only two individuals captured recently, which were transferred to the Aquaculture Station of Federal University of Santa Catarina to be preserved as part of the breeding stock. In the study performed by Cecílio *et al*. (1997) in the influence area of the Itaipu Dam, the occurrence of *B. orbignyanus* was registered only in the first two years after closing the dam, and its permanence in the environment was described by the authors as endangered due to changes in the dynamics of water and food shortages imposed by damming.

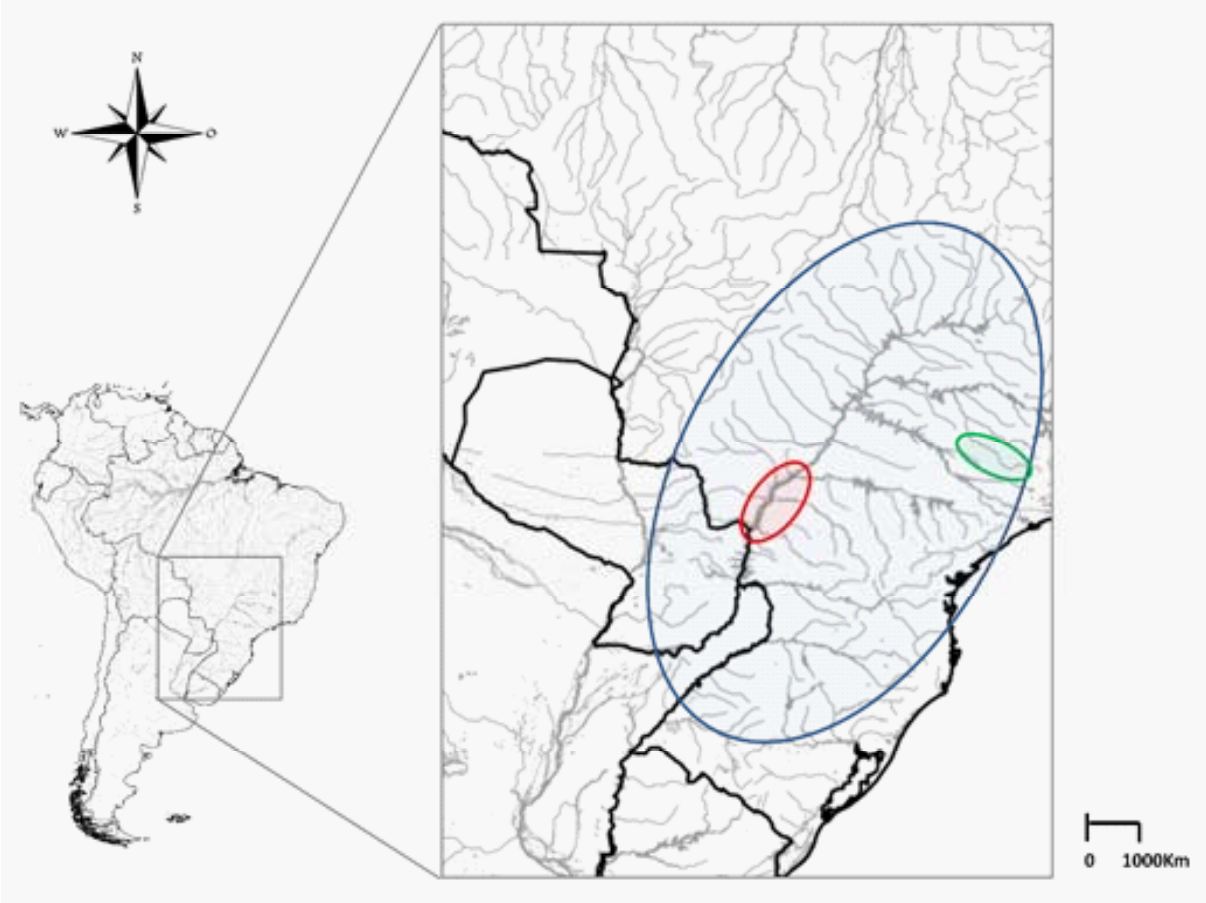

Figure 2 – Map showing the distribution of the *Brycon orbignyanus* in the Prata Basin in the blue circle. The red circle shows the free stretch of the Paraná River, which extends from the hydroelectric dam of Itaipu to the dam of the Porto Primavera. The green circle shows the Mogi-Guaçu river where the occurrence of this species is currently rare.

Main threats affecting species

The Paraná River basin is in one of the most densely populated region of the Brazil (Agostinho *et al*. 2007), which demands an increased requirement of water supply by industry and agriculture. Because of the demographic occupation process, large amounts of organic and inorganic waste from cities and agriculture are dumped daily into the environment and, consequently, have their final deposition in the aquatic ecosystem. This discharge of pollution diminishes water quality and is frequently associated with mortality of aquatic organisms by poisoning the environment with chemical substances and eutrophication. Associated to this, the processes of destruction of riparian vegetation along watercourses and silting of river environments may cause destruction or modification of favorable areas for spawning and refuge of different species of fish, which interrupts the consolidation of reproduction and causes environmental changes that eliminate the presence of certain species (Agostinho & Gomes 2005).

Another factor to be noted is the presence of numerous dams in Brazilian rivers, including the example in the Paraná River basin, which are among the most impactful hydrographic systems as they present the greatest number of dams in South America. According to ANEEL (Agência Nacional de Energia Elétrica, 2003) There are more than 130 dams in this hydrographic basin, considering only those that are greater than 10 meters in height. These endeavors turned the Paraná River and its major tributaries into a succession of lakes, changing the characteristics

of lotic to lentic rivers (Sirol & Britto 2006). The effects of the environmental fragmentation for fish populations are numerous, with considerable influence on the biological characteristics of species regarding feeding and maintenance, adaptation to changing environmental conditions, and disruption of migratory routes for feeding and reproduction (Agostinho *et al*. 2005). Besides acting on environmental conditions with consequential modification of the genetic structure of the populations, the interruption of gene flow may result in a decrease of genetic variability, increased inbreeding, and consequently, decreased adaptability of progenies (Ward 2006). It is also possible to detect expressive changes in the recruitment of fish upstream, alteration in limnological characteristics, and an increased susceptibility to infestation with parasites because the pattern of flooding cycle of rivers is also modified (Taylor *et al*. 1984). The association of these factors may contribute strongly to the disappearance of fish species, including many *Brycon* species.

The introduction of exotic species can be considered as another threatening event to biodiversity (Vitule *et al*. 2013). Per Moura-Britto and Patrocinio (2005), major alien species in the Paraná River basin are *Colossoma macropomum, Hoplias lacerdae*, different *Cichla* spp., *Odontesthes bonariensis, Oncorhynchus mykiss, Oreochromis niloticus, Cyprinus carpio*, and *Clarias gariepinus*. The consolidation and balance of the exotic species in the new environment occur in most cases with a high dominance of invasive species on site, modifying the original conditions of habitats with the loss of biodiversity, altering species richness, and their biological processes (Breton *et al*. 2005).

Fishing is also a factor that influences population equilibrium of the major commercial species. Studies have shown that most fisheries currently operating in natural stocks in freshwater environment are reaching a level of overfishing or are close to the biological limit of the species (Agostinho *et al*. 2007). In this sense, the high demand of fishery products lead to an increase of fish exploitation, and appropriate measures are promptly necessary to ensure the sustainable use of natural resources because they are finite. Due to an aggressive desirable behavior for sport fishing and because of the excellent meat quality, which is greatly sought out for consumption, *B. orbignyanus* has become a major target to fishery in recent years (Melo 1994, Vaz *et al*. 2000). It must be considered that during the spawning season in Cachoeira de Emas (Mogi-Guaçu River, Pirassununga, SP, Brazil), between 1942 and 1943, 1606 pounds of "piracanjuba" were captured, representing a high valuable market fishery (Godoy 1945), and during recent years, only one individual was captured in this river (Senhorini 2011 personal communication). This fact points to the need for interference and a consistent proposal of appropriate, associated management actions performed in critical habitats of migratory species, as to ensure better conditions for wild populations and preservation of their stocks.

Potential for conservation

Involvement of research institutions

The Centro Nacional de Pesquisa e Conservação da Biodiversidade Aquática Continental (CEPTA) of the Chico Mendes Institute (ICMBio) is executing a research program aiming to investigate the genetic and reproductive aspects of *Brycon orbignyanus* to generate information for the preservation of this species. The main objectives of this study are the characterization of the genetic structure of wild stocks of the species from different localities of the La Plata River basin, the formation of a gene bank of the species, and to study the process of reproduction in natural environment and in captivity (Brasil 2012).

Other researchers are in progress at different institutions, such as the Federal University of Lavras, MG, Brazil (UFLA), the Federal University of Viçosa, MG Brazil, (UFV), and the Aquiculture Center of Jaboticabal, SP, Brazil (CAUNESP), which develops studies related to fish larvae hatchery and cryopreservation of germplasm rheophilic native fish and reproduction, including research with *B. orbignyanus* (Viveiros *et al*. 2010, Landines *et al*. 2010, Miliorini 2012, Paes *et al* .2014

Chiacchio 2016). The Federal University of Santa Catarina-, Florianópolis, SC, Brazil (UFSC) has studied the occurrence of the species in the Uruguay River basin and presently develops studies related to induced reproduction and breeding of larvae and juveniles, in addition to research on genetics and conservation of endangered fish species (Brol 2006, Reynalte-Tataje *et al*. 2004). Recently, a partnership formed between the Paulista State University "Julio de Mesquita Filho" (UNESP/Botucatu, SP, Brazil) and CEPTA/ICMBio, aiming to conduct studies on the conservation of native fish species, accomplished population genetic analysis on *B. orbignyanus*. Sampling for analysis covered the large tributaries in the upper part of the La Plata River basin mainly, aiming to quantify the genetic variability of natural stocks and those held in captivity for use in hatcheries, while generating data that can support program management for the conservation of this species (Abe *et al*. 2014, Ashikaga *et al*. 2015, Oliveira *et al*. 2015, Travenzoli *et al*. 2015).

Natural populations

The "piracanjuba" is characterized as a very selective species with respect to environmental conditions. Its omnivorous feeding habit determines its preference for foraging areas containing the marginal vegetation of hydrographic components, and it uses these elements mainly for food and protection (Ceccarelli *et al*. 2005). The increased intervention of human action on this specific environment have caused its drastic reduction and even elimination from the river banks in the most extreme cases. This is reducing the possibilities of occupancy and maintenance for many species, leads to decline of fish populations, and even the extinction of numerous species (Frankham *et al*. 2002). In the specific case of *Brycon orbignyanus*, genetic population studies conducted in samples from populations found in the natural environment (Ashikaga *et al*. 2015) revealed the existence of some preserved natural stocks, which still retain significant genetic variability. According to the author, areas with better environmental conditions are coincident with the presence of individual groups with higher rates of genetic variability. Future management actions should consider the Ivinhema River, Verde River, and the National Park of Ilha Grande located along the medial region of the Paraná River basin as independent evolutionary units and as priority areas for the implementation of conservation programs for this species. It is considered that such populations and the environment where they are found should be preserved to establish effective genetic banks.

Populations in captivity

In general, the largest captivity stocks of *B. orbignyanus* are in fish farms that produce individuals by induced reproduction to meet the consumer market or to produce progenies used in restocking programs, which has been carried out mainly by electricity power generators. Hydroelectric dams cause changes and interfere with almost all aquatic fauna, of which are those species which perform reproductive migration being the most affected (Agostinho *et al*. 2005). Among the companies that own fish farms involved in the production of *B. orbignyanus* for restocking programs, the China Three Gorges (CTG) stand outs as being responsible for the Aquaculture and Hydrology Station of Jupiá, located in Castilho, SP, and the Energetic Company of Minas Gerais (CEMIG) owns two aquaculture stations, one in the Volta Grande Environmental Unit located between the towns of Miguelópolis-SP and Conceição das Alagoas-MG and another station in the municipality of Itutinga-MG.

In Passos-MG, the Furnas Hydroelectric Power Plant also has a large breeding stock of various species of migratory fish, including *B. orbignyanus*. The Itaipu Hydroelectric Power Plant located in the city of Foz do Iguaçu-PR developed a breeding program for fish in the Paraguayan area of their dam. The Duke Energy International, which owns the Hydrobiology and Aquaculture Station located in the municipality of Salto Grande-SP, also has similar operations. Beyond the major institutions cited, other institutions also have stocks of this species, which are used in conservation

programs, such as the Federal University of Santa Catarina (UFSC) and CEPTA/ICMBio that maintain live specimens captured in the Uruguay River and Ivinhema River, respectively, in their aquaculture stations.

The genetic variability was studied in most of these captive stocks by Ashikaga *et al*. (2015) and revealed poor values of diversity and a high degree of inbreeding of the parental lines used as bloodstocks in the reproductive process. The analysis also revealed that the progenies obtained and used in restocking programs were quite homogeneous, resulting in a gradual process of decline in genetic diversity of the species in these environments (Ashikaga *et al*. 2015). Many fish farm stations whose principal activity is the production of specimens intended for restocking programs have breeder stocks presenting a high degree of inbreeding and, consequently, low genetic variation (Oliveira 2014). The release of individuals produced in such condition to restore problematic environments will certainly establish undesirable conditions of genetic homogeneity (Oliveira 2014, Ashikaga *et al*. 2015). Moreover, this fact may jeopardize the genetic stability of the wild populations because of possible interbreeding between wild populations rich in variability and poor quality stocks kept in captivity (Oliveira 2014, Ashikaga *et al*. 2015).

Conservation plans

An important step for conservation of biodiversity was the creation of three protected areas between the dams of Primavera Port and Itaipu in a stretch of 130 kilometers of running waters of the Paraná River. The proposal includes the "Environmental Protection Area of Islands and Floodplain from the Paraná River" with approximately 10,031 square kilometers of protected areas; the National Park of Ilha Grande with 788 square kilometers and Ivinhema State Park with approximately 700 square kilometers. This constitutes a crucial need to define priority areas for conservation, and within these limits, the native species are protected and, therefore, prohibited from being exploited.

Among the actions already implemented for the protection of endangered species, it can be highlighted in the Normative Instruction Nº. 5/2004. This prohibits the exploitation of endangered aquatic invertebrates and fish, including *B. orbignyanus*, by subjecting the violators to fines, confiscation of fishing equipment, and sentences of one to three years of imprisonment, which is currently enforced through ordinance 445/2014.

To relieve the pressures of fishing on natural populations, especially on endangered species such as the "piracanjuba", investment in aquaculture programs would be an interesting alternative, although this practice is not considered an activity of management of fisheries resources (Agostinho *et al*. 2005). However, despite aquaculture activities having their economic importance and being considered as an efficient way to produce food, it still has a weak scientific basis in its conservationist view. Most the research effort expended in this area is focused on the development of manufacturing technologies and the management of environmental conditions inside the tanks, while little being investigated about the sustainability of the species in wild environment (Agostinho *et al*. 2007).

Many management programs for aquatic fauna include the restructuring of riparian vegetation, considering its importance as a refuge for numerous species, in addition to providing food, protecting waterways, preventing erosion, and preserving biodiversity. Per the Brazilian Forest Code (Law Nº 12651/2012), riparian vegetation must remain untouched; however, promoting its immediate recovery is required if degraded. The preservation of the riparian vegetation increases opportunities for fish to finding propitious areas for spawning and feeding. Also, the Brazilian environmental legislation still has a specific article that prohibits the introduction of species within the country (Law Nº 5197, of January 3, 1967, Article 4º): "No species can be introduced into the country without the consent of specialized federal analysts and a license issued in the form of law". In this case, the chances of preserving wild and natural populations can be vastly increased by avoiding mixture and competition with foreign or invasive species.

Because of Law Nº. 9991 from July 24, 2000, it was established that power generation companies are obligated to invest 0.2% of its Net Operating Revenue (NOR) in the Annual Program of Research and Technological Development from the Electric Sector, regulated by the National Agency of Electric Energy (ANEEL). Other laws such as the Provisional Measure Nº 144/2003, the law Nº 10848/2004, and the law Nº 11465/2007 underwent changes since the first law in year 2000 to foster the law Nº 12212 of January 20, 2010, which currently establishes the requirement to invest 0.5% of their NOR for both research and development and for energy efficiency programs as of 31/12/2015. The requirement for investment in research favored several areas of study, including those related to environment preservation, making the development of projects for conservation and management of the aquatic fauna possible.

The current conservation status of Brycon species

The occurrence of wild specimens of *B. orbignyanus* was detected in a stretch of flowing waters in the Paraná River between the Itaipu Reservoir and Primavera Port, characterized by a wide channel composing an extensive fluvial plain with large and small islands and a narrower floodplain area (Figure 2) (Agostinho *et al*. 1995). In this environment, the remnants of floodplain play an essential role in maintaining the biodiversity of fish, especially the migratory species. Nevertheless, specimens of this species are increasingly rare in the Uruguay River and its tributaries, which also still present long stretches of flowing waters like that found in the Paraná River. Only two wild specimens, which are maintained in the wild bloodstock of the São Carlos Aquaculture Station, Santa Catarina State, were captured in the last years (Zaniboni-Filho & Nuner 2008).

The building of successive dams that formed a cascade system in the large Brazilian rivers is causing disruption of the migratory routes because of fragmentation of natural lotic environments of flowing waters and their replacement by lentic environments, which results in the disappearance of some migratory fish species (Carvalho et al. 2005). In studies on the fish fauna of the Salto Grande Dam on the Paranapanema River, Brandão (2007) concluded that fish species with high trophic plasticity and rapid reproduction are better suited to the conditions of these semi-artificial lentic ecosystems than migratory species. Additionally, two other factors must be considered as effects of the deployment of a hydroelectric dam. First, there are the modifications of the natural flood regime of the floodplains, as observed in the upper Paraná River that was previously regulated by the annual rainfall cycle and is now dependent on the controlled water level in the reservoirs. Secondly, there is flooding of native riparian vegetation, which causes numerous problems to the ecosystem (Agostinho & Gomes 2005)., such as the destruction of protected areas for feeding and reproduction, silting of rivers, water pollution by leaching of agricultural inputs, dumping of products from human settlements and industrial discharges, decomposition of submerged organic matter producing methane gas and encouraging the growth of algae, among others (Agostinho *et al*. 1995, Conte *et al*. 1995, Rodrigues & Gandolfi 2001, Agostinho & Gomes 2005). According to Merona (1986), changes in the habitat can directly influence biological functions such as growth and reproduction, given tnat organisms like fish are essentially dependent on these functions to keep their stocks. In the case of *B. orbignyanus*, this species also has its survival drastically threatened by changes in environmental characteristics, mainly due to its sensitivity to changes in the dynamics and quality of water, availability of allochthonous food, and interruption of migratory routes (Cecílio *et al*. 1997).

Recently, the introduction of species for aquaculture has become an increasingly common practice. It is performed most often with poor planning with users considering just the profit or the increase in productivity for the short term and ignoring the environmental damage, the future consequences, and even the current legislation (Vitule 2007). When a species of fish is introduced into a "new" environment, its presence may lead to changes in habitat, community structure, hybridization, loss of genetic resources, and introduction of diseases and parasites (Taylor *et al*. 1984, Welcomme 1998). It sometimes also leads to the extinction of native species

and, therefore, loss in biodiversity (Cambray 2003). The biodiversity of native fish can also be threatened by the presence of hybrids alone because of cases where offspring resulting from crosses of different species are sterile (Hashimoto *et al*. 2013, Porto-Foresti *et al*. 2013). However, considering that interspecific hybrids obtained with *B. orbignyanus* are generally fertile in their generations (Ponzetto *et al*. 2009), this result can affect the stability of wild populations because they should occupy the same niche. In the case they remain a part of the parental lines without contributing to the effectiveness of the population, they can generally compete only for food and space. Alternatively, if they develop intercrossing activities with the parental lines, this can pose serious genetic contamination risks to natural stocks of wild species (Vieira & Pompeu 2001, Agostinho & Gomes 2005). According to Ponzetto *et al*. (2009), hybrids of *Brycon* obtained from interspecific crosses are very attractive for breeders, mainly because of presenting generally greater weight and length gain when compared to parents.

Among the possibilities for the management of fish populations in natural environments impacted by human actions, actions including the implementation of closed seasons, application of capture quotas, standardization of equipment types allowed for capture, and regeneration of spawning areas and growth are the most used activities (Sirol & Britto 2006). The control of fishing seeks to regulate the capture of young fish by establishing a minimum length of captured animals and catch size mesh, associated with the protection of spawning grounds during the reproductive period. However, these measures are compromised by the lack of enough information about fish populations, absence of effective financial support, and poor monetization activities (Agostinho *et al*. 2005). Thus, it can be considered that the management of fishery resources requires a broad knowledge of all components of the system, such as fish species, the environment, and the interaction established with other organisms. The integrative importance between these components is so strong that isolated actions may result in the failure of the program (Agostinho & Gomes 2005).

Restocking programs of the species B. orbignyanus are being further explored in Brazil to increase its survival and conservation (Sirol & Britto 2006). However, their application and use is still limited because there is no guide for use, which results in a fish stock of low genetic diversity that may bring harm to native populations (Povh *et al*. 2008). Even though restocking programs are well accepted by society (Sirol & Britto 2006) and part of the scientific community, it is important to introduce the genetic and biological monitoring to such activity, since restocking may represent a risk to natural populations (Sonstebo et al. 2007) and to the ecosystem (Agostinho & Gomes 2005). The need to include species in the program, protection of genetic variability of wild populations, location and periods to release the progenies, minimum body size of individuals, amount and frequency of release captivity populations are all important points to be considered in the management of restocking programs (Sirol & Britto 2006). According to Lopera-Barrero *et al*. (2008), it is necessary to develop the genetic management of the progenies to minimize the loss of genetic variability in captive breeding and also to respect the population genetic structure when present. The genetic analysis in hatchery stocks represents important information to achieve significant results in the conservation of fish stocks because the loss of genetic variability is very common in fish farming due to inadequate management of breeding individuals (Sonstebo *et al*. 2007, Povh *et al*. 2008).

The recovery of natural environments and the construction of transposition mechanisms of fish as ladders and elevators in hydroelectric dams can also be used (Agostinho & Gomes 2005, Sirol & Britto 2006) and provide interesting tools in the management and monitoring of fish fauna. However, the fact these mechanisms can lead to failure must be taken into consideration because they present high species selectivity and essentially unidirectional movements of fish (Agostinho & Gomes 2005). The study performed by Sirol & Britto (2006) in the fish ladder of the Canoas Complex proved the efficiency of this mechanism in the transposition of fish across the dam. However, it also revealed the non-selectivity of the mechanism, enabling the crossing of species of migratory and non-migratory fish.

Monitoring should be considered as an essential step that must follow all management actions, including transposition of fish, stocking and restocking activities, habitat manipulation, control of fishing, amongst others, as it is an indispensable assessment tool for the conservation of natural resources (Oliveira 2014). The absence of management actions does not exempt the monitoring of species (Estrela *et al*. 2006) because an efficient monitoring process is recommended for detecting the effects of any environmental change. When identified, monitoring enables faster decisions and makes preventing or mitigating the impacts possible.

Final considerations

Despite the importance of fish to humans for either food, entertainment, or as an important element in the ecological structure of environments, knowledge on the diversity found mainly in the Neotropical region is still insufficient as an expressive number of species, knowing that the diversity is extremely large. Furthermore, the constant changes in the environment by human action have increasingly restricted available areas for occupancy and the maintenance of many species, which have also resulted in the decline of fish populations and even their extinction. In this context, restocking programs have become necessary as a broad scientific discussion involving genetics, ecology, physiology, reproduction, and the participation of other areas that allow for determining which species, systems, techniques, and strategies must be used. The existence of wild stocks that still preserve the original genetic variability of the species revealed by Ashikaga *et al* (2015) pointed to the need for intensive studies to generate a better understanding on the current situation of remaining wild stocks, as well as the development of adequate management and preservation programs for the species.

It should be emphasized that there is a need for using appropriate conservation practices, adequate management of blood stocks, and the progenies obtained in growing conditions. In the restocking programs, it is necessary to introduce individuals who promote the maintenance or restoration of genetic variability of the species in the environment. In addition, it is also necessary to consider that conservation programs should focus on the recovery of degraded environments to allow for the installation of restocking programs. Similarly, preserved environments such as those found in the middle region of the Paraná River basin, which still has stocks genetically preserved (Ashikaga 2013), should be transformed into areas of environmental protection to ensure the permanence of species.

Thus, the management of stocks of *B. orbignyanus* requires an interdisciplinary approach where different scientific studies provide data for the preparation of effective and robust management plans (Aho *et al*. 2006, Oliveira 2014, Ashikaga *et al*. 2015). Under these circumstances, the integrative action of different research areas, federal government, and companies involved in electric energy generation is very important to join efforts and resources towards the conservation of biodiversity.

Acknowledgment

CNPq process108296 / 2010-5

We would also like to thank Michael James Stablein of the University of Illinois Urbana-Champaign for his translation and English revision services in this work.

References

Abe, K.T. *et al*. 2014. Systematic and historical biogeography of the Bryconidae (Ostariophysi: Characiformes) suggesting a new rearrangement of its genera and an old origin of Mesoamerican ichthyofauna. **BMC Evolutionary Biology**, 14: 152.

Agostinho, A.A. & Gomes, L.C. 1997b. **Reservatório de Segredo: bases ecológicas para o manejo**. EDUEM. 387p.

Agostinho, A.A. & Gomes, L.C. 2005. O manejo da pesca em Reservatórios da bacia do Alto Rio Paraná: Avaliação e Perspectivas. *In*: Nogueira, M.G.; Henry, R.; Jorcin, A. **Ecologia de reservatórios: impactos potenciais, ações de manejo e sistemas em cascata**. 1 ed. Rima, 2: 23-55.

Agostinho, A.A. *et al*. 2002. Efficiency of fish ladders for neotropical ichthyofauna. **River Research and Applications**, 18: 299-306.

Agostinho, A.A.; Gomes, L.C. & Pelicice, F.M. 2007. **Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil**. EDUEM. 501p.

Agostinho, A.A.; Thomaz, S.M. & Gomes, L.C. 2005. Conservation of the Biodiversity of Brazil's Inland Waters. **Conservation Biology**, 19: 646-652.

Agostinho, A.A.; Vazzoler, A.E.A.M. & Thomaz, S.M. 1995. The high river Paraná basin: limnological and ichthyological aspects. p. 59-103. *In*: Tundisi, J.G.; Bicudo, C.E.M. & Matsumura-Tundisi, T. **Limnology in Brazil**. ABC/SBL. 384p.

Agostinho, A.A. *et al*. 2007. Fish diversity in the upper Paraná River basin: habitats, fisheries, management and conservation. **Aquatic Ecosystem Health & Management**, 10: 174-186. Informa UK Limited. http://dx.doi.org/10.1080/14634980701341719.

Aho, T. *et al*. 2006. Impacts of effective population size on genetic diversity in hatchery reared Brown trout (*Salmo trutta* L.) populations. **Aquaculture**, 253: 244-248.

Ashikaga, F.Y. 2013. **Análise da Estrutura Genética de *Brycon orbignyanus* na Bacia do Rio Paraná para Fins de Conservação**. Tese (Doutorado em Zoologia). Universidade Estadual Paulista, Botucatu. 82p.

Ashikaga, F.Y.; Orsi, M.L.; Oliveira, C.; Senhorini, J.A. & Foresti, F. 2015. The endangered species B*rycon orbignyanus*: genetic analysis and definition of priority areas for conservation. **Environmental Biology of Fishes**, 96: 1-13. http://doi.org/10.1007/s10641-015-0402-8.

Brandão, H. 2007. **A ictiofauna da represa de Salto Grande (médio rio Paranapanema – SP/PR): composição, estrutura e atributos ecológicos**. Dissertação (Mestrado em Zoologia). Universidade Estadual Paulista, Botucatu. 67p.

Machado, A.B.M; Drummond, G.M & Paglia, A.P (eds.). 2008. **Livro Vermelho da Fauna Ameaçada de Extinção**. Fundação Biodiversitas; Ministério do Meio Ambiente. 270p.

Brasil, 1967. Lei n° 5.197, de 3 de janeiro de 1967. Dispõe sobre a proteção à fauna e dá outras providências. **Diário Oficial da União**. <http://www.planalto.gov.br/ccivil_03/leis/L5197.htm>

Brasil, 2000. Lei nº 9.991, de 24 de julho de 2000. **Diário Oficial da União**. Dispõe sobre realização de investimentos em pesquisa e desenvolvimento e em eficiência energética por parte das empresas concessionárias, permissionárias e autorizadas do setor de energia elétrica, e dá outras providências, p. 43-76. *In*: ANEEL (ed.), **Atlas de Energia Elétrica do Brasil**. 2003.

Brasil, 2004. Lei nº 10.848, de 15 de março de 2004. Dispõe sobre a comercialização de energia elétrica, altera as Leis nºs 5.655, de 20 de maio de 1971, 8.631, de 4 de março de 1993, 9.074, de 7 de julho de 1995, 9.427, de 26 de dezembro de 1996, 9.478, de 6 de agosto de 1997, 9.648, de 27 de maio de 1998, 9.991, de 24 de julho de 2000, 10.438, de 26 de abril de 2002, e dá outras providências. **Diário Oficial da União**, Seção 1, 51, 16/03/2004: 2.

Brasil. 2007. Lei nº 11.465, de 28 de março de 2007. Altera os incisos I e III do caput do art. 1º da Lei nº 9.991, de 24 de julho de 2000, prorrogando, até 31 de dezembro de 2010, a obrigação de as concessionárias e permissionárias de serviços públicos de distribuição de energia elétrica aplicarem, no mínimo, 0,50% (cinquenta centésimos por cento) de sua receita operacional líquida em programas de eficiência energética no uso final. **Diário Oficial da União**. <http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2007/Lei/L11465.htm>

Brasil. 2010. Lei nº 12.212, de 20 de janeiro de 2010. Dispõe sobre a Tarifa Social de Energia Elétrica. **Diário Oficial da União**, Seção 1, 14, 21/01/2010: 1.

Brasil. 2012. Lei n° 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166- 67, de 24 de agosto de 2001; e dá outras providências. **Diário Oficial da União**, Seção 1, 102, 28/05/2012: 1.

Breton, H. *et al*. 2005. Liquid chromatography-electrospray mass spectrometry determination of carbazepine, oxcarbazepine and eight of their metabolites in human plasma. **Journal of chromatography. B, Analytical technologies in the biomedical and life sciences**, 828: 80-90.

Britski, H.A.; Sato, Y. & Rojsa, A.B.S. 1988. **Manual de Identificação de Peixes da Região de Três Marias (com chaves de identificação para os Peixes da Bacia do São Francisco)**. 3ed. CODEVASF, Câmara dos Deputados. 115p.

Brol, F.F. 2006. **Influência do cultivo de *Brycon orbignyanus* em tanques-rede sobre a qualidade da água do reservatório da Usina Hidrelétrica Machadinho**. Dissertação (Mestrado em Aquicultura). Universidade Federal de Santa Catarina. 36p.

Cambray, J.A. 2003. The need for research and monitoring on the impacts of translocated sharptooth catfish, *Clarias gariepinus*, in South Africa. **African Journal of Aquatic Science**, 28: 191-195.

Carvalho, E.D. *et al*. 2005. Fish assemblage attributes in a small oxbow lake (Upper Paraná River Basin, São Paulo State, Brazil): species composition, diversity and ontogenetic stage. **Acta Limnologica Brasiliensia**, 17(1): 45-56.

Cavalcanti, C.A. 1998. **Proteases digestivas em juvenis de piracanjuba (*Brycon orbignyanus* Eigenmann, 1909) e aplicação da técnica de digestibilidade *"in vitro"***. Dissertação (Mestrado em Aquicultura). Universidade Federal de Santa Catarina. 101p.

Ceccarelli P.S.; Senhorini J.A. & Rego R.F. 2005. Piracanjuba, *Brycon orbignyanus* (Valenciennes, 1849), p.121-147. *In*: Baldisserotto B. & Gomes L.C. **Espécies nativas para piscicultura no Brasil**. 1 ed. Editora da Universidade Federal de Santa Maria. 472p.

Cecílio, E.B. *et al*. 1997. Colonização ictiofaunística do reservatório de Itaipu e áreas adjacentes. **Revista Brasileira de Zoologia**, 14: 1-14.

Chiacchio, I.M. 2016. **Qualidade do sêmen e sua estação reprodutiva em *Prochilodus lineatus* e *Brycon orbignyanus***. Dissertação (Mestrado em Zootecnia). Universidade Federal de Lavras. 58p.

Conte, L.; Bozano, G.L.N. & Ferraz de Lima, J. 1995. A influência do sistema de alimentação no crescimento da piracanjuba *Brycon orbignyanus*, em gaiolas. **Boletim Técnico CEPTA**, 8: 49-59.

Eckmann, R. 1984. Induced reproduction in *Brycon* cf. *erythropterus*. *Aquaculture*, 38: p. 379-382. *In*: Estrela, M.R. *et al*. 2006. Recomendações para o manejo pesqueiro em reservatórios. **Seminário: Manejo Pesqueiro em Reservatórios**, de 14 a 16/3/2006. CESP Jupiá.

FAO. 2016. **The State of World Fisheries and Aquaculture 2016**. Contributing to food security and nutrition for all. Rome. 200p.

Frankham, R. 2005. Genetics and extinction. **Biological Conservation**, 126: 131-140.

Frankham, R.; Briscoe, D.A. & Ballou, J.D. 2002. **Introduction to conservation genetics**, Cambridge University Press. 617p.

Godoy, M.P. 1945. A piracema de 1944/1945 no rio Mogi Guassu, Cachoeira de Emas. **Boletim Ministério da Agricultura**, 34 (3): 103-109.

Godoy, M.P. 1975. **Peixes do Brasil: subordem Characoidei; bacia do rio Mogi Guassu**. Ed. Franciscana.

Hahn, N.S. *et al*. 1998. Estrutura trófica da ictiofauna do reservatório de Itaipu nos primeiros anos de sua formação. **Interciência**, 23: 299-305.

Hashimoto, D.T. *et al*. 2013. Detection of post-F1 catfish hybrids in broodstock using molecular markers: approaches for genetic management in aquaculture. **Aquaculture Research**, 44: 876-884.

Hilsdorf, A.W. & Petrere, M.J.R. 2002. Conservação de peixes na bacia do rio Paraíba do Sul. **Ciência Hoje**. 30: 62-67.

Ibama (Instituto Brasileiro do Meio Ambiente e dos recursos Naturais Renováveis), 2007. Instrução Normativa nº 146, de 10 de janeiro de 2007. **Diário Oficial da União**, Seção 1, 8, 11/01/2007: 56-57.

Landines, M.A.; Sanabria, A.I.; Senhorini, J.A. & Urbinati, E.C. 2010. The influence of triiodothyronine (T3) on the early development of piracanjuba (*Brycon orbignyanus*). **Fish Physiology and Biochemistry**, 36: 1291-1296. http://doi.org/10.1007/s10695-010-9410-y.

Lauder, G.V. & Liem, K.F. 1983. The evolution and interrelationships of the Actinopterygian fishes. **Bulletin of The Museum of Comparative Zoology**, 150(3): 95-197.

Lima, F.C.T 2003. Subfamily Bryconinae, p. 174-181. *In*: Reis R.E. Kullander S.O.; Ferraris C.J. **Check List of the Freshwater Fishes of South and Central America**. EDIPUCRS. 734p.

Lopera-Barrero N.M. *et al*. 2008. Caracterización genética de lotes de *Brycon orbignyanus* utilizados en programas de repoblamiento. **Revista MVZ Córdoba**, 13: 1110-1119.

MMA (Ministério do Meio Ambiente), 2004. Instrução Normativa nº 5, de 21 de maio de 2004. **Diário Oficial da União**, Seção 1, 102, 28/05/2004: 136-142.

MMA (Ministério do Meio Ambiente), 2012. Portaria nº 23, de 17 de fevereiro de 2012. **Diário Oficial Da União**. <http://www.icmbio.gov.br/portal/images/stories/docs-plano-de-acao/pan-mogi-pardo/portaria_panmogi.pdf>

MMA (Ministério do Meio Ambiente), 2014. Portaria nº 445, de 17 de dezembro de 2014. **Diário Oficial da União**, Seção 1, 245, 18/12/2014: 126.

Melo, J.S.C. 1994. Criação de espécies do gênero *Brycon*. *In*: **Anais do Seminário sobre criação de espécies do gênero *Brycon***, CEPTA.

Merona, B. 1986. Aspectos ecológicos da ictiofauna no Baixo Tocantins. **Acta Amazônica Acta. Amazônica**, 16/17: 109-457.

Miliorini, S.B. 2012. **Resfriamento e congelamento de embriões de dourado (*Salminus brasiliensis*), piracanjuba (*Brycon orbignyanus*) e piapara (*Leporinus obtusidens*)**. Tese (Doutorado em Ciências Veterinárias). Universidade Federal de Lavras. 138p.

Moura-Britto, M. & Patrocínio, D.N.M. 2005. A fauna de espécies exóticas no Paraná: contexto nacional e situação atual, p. 53-91. *In*: **Unidades de Conservação: Ações para valorização da biodiversidade**. Instituto Ambiental do Paraná – IAP. 349p.

Nelson, J.S. 2006. **Fishes of the world**. J Wiley and Sons, Inc. Honboken.4 ed. 600p.

Oliveira, C. *et al*. 2011. Phylogenetic relationships within the speciose family Characidae (Teleostei: Ostariophysi: Characiformes) based on multilocus analysis and extensive ingroup sampling. **BMC Evolutionary Biology**, 11: 275-285.

Oliveira, D.J. 2014. **Reprodução em cativeiro de piracanjuba *Brycon orbignyanus* assistida por marcador molecular como estratégia de conservação**. Dissertação (Mestrado em Ciências Biológicas – Zoologia). Universidade Estadual Paulista. 39p.

Oliveira, D.J.; Ashikaga, F.Y.; Foresti, F. & Senhorini, J.A. 2015. Indução a reprodução artificial e caracterização espermática da piracanjuba *Brycon orbignyanus* (Bryconidae, Characiformes), espécie em perigo de extinção. **Evolução e Conservação da Biodiversidade**, 5(2), 10. hhttp://doi.org/10.7902/ecb.v5i2.71

Oyakawa, T.O.; Menezes, N.A.; Shibatta, A.O.; Lima, F.C.T; Langeani, F.; Pavanelli, C.S.; Nielsen, D.T.B. & Hilsdorf, A.W.S. 2009. Peixes de água doce, p. 350-424. *In*: Bressan, P.M.; Kierulff, M.C.M. & Sugieda, A.M. (eds.). **Fauna ameaçada de extinção no Estado de São Paulo: Vertebrados**. Fundação Parque Zoológico de São Paulo, Secretaria do Meio Ambiente. 648p.

Paes, M.D.C.F.; Da Silva, R.C.; Nascimento, N.F.; Valentin, F.N.; Senhorini, J.A. & Nakaghi, L.S.O. 2014. Hatching, survival and deformities of piracanjuba (*Brycon orbignyanus*) embryos subjected to different cooling protocols. **Cryobiology**, 69(3): 451-456. http://doi.org/10.1016/j.cryobiol.2014.10.003.

Ponzetto, J.M. *et al*. 2009. Reprodução induzida de híbridos do gênero *Brycon* em cativeiro: Potencialidades e ameaças a conservação das espécies nativas. *In*: 8ª. Jornada Científica e Tecnológica da UFSCar, 2009, São Carlos. **Anais de Eventos da UFSCar 5**.

Porto-Foresti, F. *et al*. 2013. Genetic Markers for the Identification of Hybrids among Catfish Species of the Family Pimelodidae. **Journal of Applied Ichthyology**, 29:643-647.

Povh, J.A. *et al*. 2008. Monitoreo genético en programas de repoblamiento de peces mediante marcadores moleculares. **Ciencia e Investigación Agraria** (Impresa), 35: 5-15.

Reis, R.E.; Albert J.S.; Di Dario, F.; Mincarone, M.M.; Petry, P. & Rocha L.A. 2016. Fish biodiversity and conservation. *In*: **South America. Journal of Fish Biology**, 89(1): 12-47. http://doi.org/10.1111/jfb.13016.

Reis, R.E.; Kullander, S.O. & Ferraris-Jr, C.J. 2003. **Check list of the freshwater fishes of South and Central America**. Edipucrs, 742p.

Reynalte-Tataje, D.; Zaniboni-Filho, E. & Esquivel, J.R. 2004. Embryonic and larvae development of piracanjuba, *Brycon orbignyanus* Valenciennes, 1849 (Pisces, Characidae). *Acta Scientiarum* – **Biological Sciences**, 26(1): 67-71. http://doi.org/10.4025/actascibiolsci.v26i1.1660.

Ribeiro-Filho, R.A. *et al*. 2011. Itaipu Reservoir limnology: eutrophication degree and the horizontal distribution of its limnological variables. **Brazilian Journal of Biology**, 71: 889-902.

Rocha, O. *et al*. 2005. **Espécies invasoras em águas doces: estudo de caso e propostas de manejo**, p. 181-196. UFSCar. 416p.

Rodrigues, R.R. & Gandolfi, S. 2001. Conceitos, tendências e ações para a recuperação de florestas ciliares, p. 235-247. *In*: Rodrigues R.R. & Leitão Filho H.F. **Matas Ciliares: conservação e recuperação**. EDUSP. 320p.

Schubart, O. 1943. A pesca na Cachoeira de Emas do rio Mogi-Guaçu durante a piracema de 1942-1943. **Boletim Indústria Animal**, 6(4): 93-116.

Sirol R.N. & Britto S.G. 2006. Conservação e manejo da ictiofauna: repovoamento, p. 275-284. *In*: Nogueira M.G.; Henry R. & Jorcin A. **Ecologia de reservatórios: impactos potenciais, ações de manejo e sistemas em cascatas**. Editora Rima. 459p.

Solé-Cava, A.J. 2001. Biodiversidade Molecular e Genética da Conservação, p. 171-190. *In*: Matioli S.R. **Biologia Molecular e Evolução**. Editora Holos.

Sonstebo, J.H.; Borgstrom, R. & Heun, M. 2007. Genetic structure of brown trout (*Salmo trutta* L.) from the Hardangervidda mountain plateau (Norway) analyzed by microsatellite DNA: a basis for conservation guidelines. **Conservation Genetics**, Dordrecht, 8(1): 33-44.

Taylor, J.N.; Courtenay-Jr, W.R. & Mccann, J.A. 1984. Known impacts of exotic fishes in the continental United States, p. 322-373. *In*: Courtenay-Jr W.R. & Stauffer J.R. 1984. **Distribution, Biology, and Management of Exotic fishes**. Johns Hopkins University Press. 430 p.

Travenzoli, N.M.; Silva, P.C.; Santos, U.; Zanuncio, J.C.; Oliveira, C. & Dergam, J.A. 2015. Cytogenetic and Molecular Data Demonstrate that the Bryconinae (Ostariophysi, Bryconidae) Species from Southeastern Brazil Form a Phylogenetic and Phylogeographic Unit. **Plos One**, 10(9): e0137843.

Vaz, M.M.; Torquato, V.C. & Barbosa, N.D.C. 2000. **Guia ilustrado de peixes da bacia do rio Grande**. CEMIG/CETEC. 144 p.

Vieira, F. & Pompeu, P.S. 2001. Peixamentos: uma ferramenta para conservação da ictiofauna nativa? **Ciência-Hoje**, 30(175): 28-33.

Vitule, J.R.S. 2007. **Distribuição, abundância e estrutura populacional de peixes introduzidos no rio Guaraguaçu**, Tese (Doutorado em Ciências Biológicas - Zoologia) Universidade Federal do Paraná. 161p.

Vitule, J.R.S. *et al*. 2013. Ecology: Preserve Brazil's aquatic biodiversity. **Nature**. 485:309.

Viveiros, A.T.M.; Isaú, Z.A.; Figueiredo, H.C.P.; Leite, M.A.S. & Maria, A.N. 2010. Gentamycin controls bacterial growth during refrigerated storage of piracanjuba, *Brycon orbignyanus*, semen. **Journal of the World Aquaculture Society**, 41(SUPPL. 1):57-65. http://doi.org/10.1111/j.1749-7345.2009.00333.x.

Ward, R.D. 2006. The importance of identifying spatial population structure in restocking and stock enhancement programmes. **Fisheries Research**. Asian, 9-18.

Zaniboni Filho, E. & Nuñer, A.P.O. 2008. **Reservatório de Itá: estudos ambientais, desenvolvimento de tecnologias de cultivo e conservação da ictiofauna**. Editora da UFSC. 198p.

Zaniboni Filho, E. & Schulz, U.H. 2003. Migratory Fishes of the Uruguay River, 157-194. *In*: Carolsfeld, J. *et al*. **Migratory Fishes of the South America: Biology, Social Importance and Conservation Status**. World FisheriesTrust.

Revista Biodiversidade Brasileira – BioBrasil. 2017, n. 1.

http://www.icmbio.gov.br/revistaeletronica/index.php/BioBR/issue/view/44

Biodiversidade Brasileira é uma publicação eletrônica científica do Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) que tem como objetivo fomentar a discussão e a disseminação de experiências em conservação e manejo, com foco em unidades de conservação e espécies ameaçadas.

ISSN: 2236-2886