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Review

Limitations in decision context for selection of amazonian armoured catfish acari-bodó (*Pterygoplichthys pardalis*) as candidate species for aquaculture

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Domestication of native species is essential to development aquaculture. However, complete information on criteria used to categorize fish native species is little available and scarce. The objective of this work is to perform narrative review, critically evaluating the problem to selection of amazonian armoured catfish named acari-bodó (*Pterygoplichthys pardalis*) as candidate species for aquaculture, assigning this fish species into three criteria (market; economic and biological) to apply multicriteria decision analysis methodology for multiple decision makers (fish farmers, researchers, government). The limitations in decision context and possibilities for domestication of the *P. pardalis* are discussed.

Key words: Fish farming, aquaculture, *Pterygoplichthys pardalis*, native species, multicriteria decision analysis, Amazonia, Brazil.

INTRODUCTION

Domestication is organism adaptation process to an environment provided by man (Ruzzante, 1994) or conditions (more or less controlled by man) that make possible breeding, care and feeding of organisms (Liao and Huang, 2000). According to Lorenzen et al. (2012) this involves genetic changes over generations both

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evolutionary response by changes in gene frequencies and shifts environmentally induced in developmental processes.

Clutton-Brock (1999) defines domestics animals as those that are breed in captivity for purposes of economic profit to a human community. Balon (2004) define truly domesticated organism like: (a) the individual is valued and kept for a specific purpose, (b) its breeding is subject to human control, (c) its behavior is different from that of wild ancestor, (d) its morphology and physiology exhibit variations never seen in the wild and (e) some individuals at least would not survive without human protection.

Teletchea and Fontaine (2014) explained that the domestication objective is to promote animal modification from their wild ancestors through selective breeding in captivity for traits beneficial to human usages. For these authors exist a clear dichotomy between wild (from hunting) and domesticated animals (produced in farms).

Unfortunately, the scientific knowledge of criteria used for selection of new candidate species for fish farming has many gaps, particularly in Northern Brazil, like the pirarucu (*Arapaima gigas*) and Tambaqui (*Colossoma macropomum*) (Val and Honczaryk, 1995; Almeida et al., 2006; Santos et al., 2014; Oliveira et al., 2014; Aguiar et al., 2013).

However, this is a very important issue because the ability to cultivate native species could be of many advantages, e.g., reduce the environmental impact of fish farming and promote local economy integration (Chia et al., 2009; Fontaine et al., 2009; Scorvo-Filho et al., 2010) or do exactly the opposite. Therefore, to reduce mistakes the selection of new fish farm species requires simultaneous analysis of various attributes for each alternative.

Currently there are several quantitative models to support decision makers to select candidate species for fish farming. These use various multicriteria decisions analysis (MCDA) methodologies, such as the *Multi-Attribute Untile Theory* (MAUT); *Analytic-Hierarquchy Process* (AHP) and the *Multi Criteria Decision Aid* (MCDA) (Ehrlich, 1996; Hansen and Ombler, 2008).

The acari-bodó (*Pterygoplichthys pardalis*) is loricariide with commercial importance, restricted native distribution in Amazon basin (Le François et al., 2002; Webber and Riordan, 1976; Suquet et al., 2002; Thouard et al., 1989; Jung, 2004; Moroni, 2005). Simonović et al. (2010) demonstrate according Protocol Fish Invasiveness Screening Kit (FISK) the domestication cultivation for the criterion/ *L. pardalis* be punctuated as 2 (Copp et al., 2005; Cagauan, 2007; Simonović et al., 2010). The entire life cycle of this fish is close in captivity, with wild inputs.

The objective of this work is to perform a narrative review, critically evaluating the limitations in decision context for selection the *P. pardalis* as species candidate, establish aims of the MCDA, identify decision makers (fish farmers, researchers, government) and other key players, assigning this fish species into three criteria (market; economic and biological).

Market aspects

This fish has market as ornamental fish and as food. Choice by hobbyists because the exotic appearance and to clean the aquarium by consuming algae and detritus (Simonović et al., 2010). There are traditional consumption habits (baked fish and smoked in wooden grid), *piracui* (fishmeal) and bodó stew or chowder (Castro, 1999; Câmara, 2004; Murrieta et al., 2008).

The traditional trade carried out within vessels with partially flooded basement, canoes or free fairs, decreases profitability for disposal of the waste generates dead animal in water bodies or landfills, without use of the carcasses and offal (Moroni, 2005). This fish is marketed alive because rapid process of deterioration of the animal with viscera, by extravasation of digestive enzymes (Castro, 1999; Brito, 1981; Moroni, 2005).

Lourenço et al. (2011) describe low hygiene as critical factor in processing of *piracui* (fishmeal) and indicate bacteriological stability in water activity less than 0.6 Aw. Kluczkovski and Kluczkovski Jnr. (2013) described the presence of aflatoxins in this fish product marketed in the city of Manaus, AM, Brazil. Another critical point is the drying processing. According Murueta et al. (2007) this need to be monitoring to avoid proteins overheated for not generate negative influence in protein digestion or absorption.

The meat has a low fat percent (0.19 to 0.29%) and high protein levels (14.52 to 18.54%). The fillets are not has pins within and has color range white to clear pink, soft texture, excellent flavor when cooked, attractive aspect and good reputation to the final consumer (Quéméner et al., 2002; Suquet et al., 2002; Jung, 2004; Moroni, 2005).

This fish has two types of cuts used for stews, with 42.06% of total edible parts, performance comparable to traditional fishes in aquaculture like African Catfish (*Clarias garlepius*); American catfish (*Ictalurus punctatus*), Nile tilapia (*Oreochromis niloticus*) (Souza et al., 1999a, b; Souza, 2001). The shelf life of fish stored in ice for 6 days (with viscera) and 12 days (without viscera). The pH determinations, NBV-T, protein solubility, water retention capacity and sensory and microbiological analyses revealed that the frozen fillets remained in terms of consumption by 6 months (Moroni, 2005). Cagauan (2007) describes the possibility of dry skin commercialization as handcrafts. These fish products above mentioned are list in Table 1.

BIOLOGICAL CRITERIA

P. pardalis (Castelnau, 1855), Siluriformes (catfish), family Loricariidae (Bonaparte, 1831), which groups the plecos and acaris (Isbrücker, 1980; Rapp Py-Daniel,

Table 1. List of products obtained from L. pardalis, ordered by commercial importance.

Order	Product name	References
1st	*Piracui* (fish meal)	Castro (1999); Lourenço et al. (2011); Kluczkovski and Kluczkovski Junior (2013)
2nd	Colds cuts for stew	Moroni (2005)
3rd	Frozen fillets	Moroni (2005)
4th	Crafts	Cagauan (2007)

1997). Armbruster (2004) define the phylogenetic relationships of loricariid catfishes. Armbruster and Page (2006) proposed systematic review to classify the genre *Liposarcus* inside the synonymy of *Pterygoplichthys*.

According to Rapp Py-Daniel (1997) the lateral line is composed by 29 plates and ventral region is covered by rough skin color, which has the same coloration pattern hair from the neotropical cat (Mammalia, felidae) named ocelot (*Leopardus pardalis*). The hydrodynamic body, flat belly and back rounded is covered with dermal plates with tegumentaries teeth and developed spines in the fins for defense against natural predators such as red river dolphins (*Inia geoffrensis)* and tucuxi *(Sotalia fluviatis*) (Silva and Best, 1996).

The *P. pardalis* uses brachial respiration in normal dissolved oxygen and the stomach exercises accessory respiratory organ function with optional air breathing, when available oxygen in the water is scarce (Brito, 1981; Val, 1995; Brauner and Val, 1996; West et al., 1999; Yossa and Araujo-Lima, 1998; Armbruster, 1998; Graham, 1999).

According to Brito (1981) these animals are benthics and nocturnes, which lives in groups on sites with decomposed organic matter. They are adapted in tropical climatic conditions with neutral waters and high temperatures, ranging between 23 and 28°C (Saint-Paul et al., 2000; Simonović et al., 2010). The ventral mouth (similar to suction cups) with filiform teeth and premaxilla movements is high adapted to consume detritus (lignin and cellulose) and small part of living material (algae, bacteria, fungi, and micro-invertebrates). This food type is source of energy and protein that are obtain from bottom of lakes or submerged vegetation, even in places with low environmental quality (Araujo-Lima et al., 1986; Yossa and Araujo-Lima, 1998; Leite et al., 2002; Mojía-Mojica et al., 2015).

The reproduction, in the Amazon region, occurs in the months of October through May (Brito, 1981). The acari-bodó has total spawning, oocytes with 2.40 mm. features a reproductive strategy typically in balance, because it does not perform migration, offers low fecundity and has large oocytes (Winemiller, 1989; Neves and Ruffino, 1998).

Porto et al. (2012) studied metazoan parasites fauna of *P. pardalis* captured in the Amazon River and purchased at fairs in the city of Manaus, AM, during the period of August 2006 to May 2007. Five species of helminthes found: *Monogenoidea*, *Unilatus* sp. and *Heteropriapulus* sp.; two of *Digenea*, a metacercariae of *Austrodiplostomum* sp. compacted into eyes, stomach and gonads, one of *Megacoelium spinicavum* in the stomach; one of *Acanthocephala* g*orytocephalus* sp. in the intestine.

Cerdeira et al. (2000) described this fish catches between riverside communities around the Great Lake of Monte Alegre, low Amazon, Brazil. The frequency of captures, Bailey et al. (1998) studied the characterization of fishing in riverine communities on bass of Solimões River. In this study it was found that the acari-bodó was more common during the months of October to March, supported by Saint-Paul et al. (2000) found that the abundance of fish in areas flooded by black and white water rivers in the Central Amazon.

Cyclic seasonal changes occurs in the level in water bodies at Amazon basin. Some examples of these variations are decay of macrophytes aquatic in the flooded forests and lakes and fall of the water oxygen level, with areas in anoxia for several months (Junk et al., 1983; Val and Almeida-Val, 1995; Junk, 1984; Almeida-Val et al., 1991). The *P. pardalis* has developed physiological adaptations that make it extremely tolerant to inhospitable environments for most teleost fishes, as acidic water, with low pressure of the O_2 and high pressure of CO_2 (Junk et al., 1983; Soares et al., 2006; Val, 1995). Table 2 summarizes the main adaptations carried out by *P. pardalis*.

ECONOMIC CRITERIA

According to Batista (1998) fish is the most important source of animal protein for low-Solimões/high-Amazon region, with an annual mean consumption rate of 550 g capita^{-1} day^{-1}. In this context, *P. pardalis* has regional economic importance with seasonal demand. The selling price has a high when the Amazon Rivers covers the forest and low in dry seasons, with high waste in the towns of the Amazon region. Second Ruffino et al. (2002), in 2001, 401,419 tons of *P. pardalis* were landed in the municipalities of Manacapuru, Monte Alegre, Óbidos, Parintins, Prainha and Santarém with average price of kilogram of R$ 0.44.

Table 2. Main adaptations carried out by L. pardalis in rivers and lakes of the Amazon basin.

Types of adaptation	Examples	References
A- Behavioral	Migration to other lakes and oxygenated environments	Brito, 1980
	Increased frequency of air capture, using the accessory air breathing.	Val, 1995
B- Metabolic	Assessment of erythrocyte phosphates.	Almeida-Val et al., 1991 Val, 2000
	Decrease in the activity of malate dehydrogenase	Almeida-Val and Farias, 1996
	Root effects and decrease saturation of Haldane hemoglobins by oxygen.	Brauner and Val, 1996
	Decreased activity of enzymes in the metabolism of carbohydrates, lipids and aerobic.	Hochachka and Somero, 1984; West et al., 1999
	Metabolic adjustments in heart muscle.	Bailey et al., 1999; MacCormack et al., 2003; Brauner et al., 2004, Hanson et al., 2009)
	Acid-base regulation.	Brauner et al., 2007; Harter et al., 2014;

LIMITATIONS AND POSSIBILITIES FOR DOMESTICATION of *P. pardalis*

The global demand of aquarists by *P. pardalis* has given the association between two factors: the offer of this species as ornamental fish with the exceptional adaptive capacity of this species to harsh environments. In addition, when they was accidentally released into bodies of water resulted in several world descriptions as invasive alien species (IAS), causing potential impacts to the environment, economy and human health (Levin et al., 2008; Cagauan, 2007). The oldest records, after *P. pardalis* released within continental bodies of water, are in the United States of America, in the State of Florida, in the early 1970. Currently there are reports of population explosion in this region and observing unexpected interactions like attaching to the bodies of native Florida Manatee (*Trichechus manatus latirostris*) to feed the epibiota of these animals (Simonović et al., 2010; Nico et al., 2009).

Mejía-Mojica et al. (2014) analyzed the distribution of exotic species in the tributaries of the Balsas River basin, in Mexico, recorded that the *P. pardalis* in areas with low quality water, measuring the factors dissolved oxygen, temperature, suspended solids and conductivity, while native species were confine to areas with high quality water and geographic isolation.

Seven specimens of *P. pardalis* were find near Frontera and above the Grijalva-Usumacinta River basin in Mexico (Wakida-Kusunoki et al., 2007). Mendoza-Carranza et al. (2010) described by the analysis of stable isotopes, the *P. pardalis* possibly competes for resources with native species (including some of high commercial value in fishing) in the Centla swamps, a biosphere reserve located in Tabasco, Mexico, after being introduced by international trade of ornamental fishes and have quickly dispersed from the Southwest Mexican.

Cagauan (2007) outlines that *P. pardalis* established in the Republic of the Philippines, found in the Marikinika River and Lake Paítan. Wu et al. (2011) identified the introduction of species of *P. pardalis* in Taiwan, based on the morphology and mitochondrial DNA sequences. Herder et al. (2012) described the record of *P. pardalis* in southwest of Lake Matano, in the Central region of the island of Sulawesi, in Indonesia, length 40 cm in excellent condition. There are expectative that the species may also disperse downstream and Mahalona Lake Towuti. Vaillant et al. (2011) claim that competition for limited resources may be critical for some of the endemic animals of the ecosystem of the Malili Lakes, also in Indonesia. . The date and location of the description of *L. pardalis* as invasive species are summarised in Table 3.

The negative effects on the ecological and economic aspects of the invasion reported *P. pardalis*. Environmental degradation are related with decreasing banks of water bodies; siltation in reservoirs, leaks caused by the behavior of building of galleries and tunnels, destruction of aquaculture tanks, lakes and the network of fishermen in the Philippines, South Florida and Mexico. Ecological disturbances are described by competition with native species for food resources, unexpected interspecific interactions, disruption of the food chain and decline in abundance of native species (Nico and Martin, 2001; Page and Robins, 2006; Levin et

Table 3. Dates and locations of some descriptions of L. pardalis as invasive alien species (IAE).

Country	Location	Year description	References
United States	Florida	1970	Simonović et al. (2010)
Mexico	Frontera	2005	Wakida-Kusunoki et al. (2007)
	Lagoon San Pedrito	2010	Mendoza-Carranza et al. (2010)
Servia	River Danube	2010	Simonović et al. (2010)
Filipino	Marikina River	2007	Cagauan (2007)
	Lake Paitan	2007	
Vietnam	Red River	2008	Levin et al. (2008)
Singapore	Send	1988	Page and Robin (2006)
Malaysia	Sungai Machap	1991	Page and Robin (2006)
Indonesia	Sumatra deli	1996	Page and Robin (2006)

al., 2008; Nico et al., 2009).

The introduction or movement of pathogens by aquaculture in the past is well established (Walker and Winton, 2010). Hershberger et al. (2010) demonstrates the related issue of pathogen amplification by an introduced species. Ueda et al. (2013), by science metric study of parasites of fish farming in Brazil conclude the parasitic diseases of farmed fish is still incipient. However, as opposed to the historic, largely unregulated movements of fish by aquaculture, it is now possible to screen brood fish for a variety of potential pathogens to reduce the risk that exotic diseases translocate with thefish.

The confinement associated with stressful circumstance possibility increase of the virulence of the pathogens and host susceptibility in culture system. Same sanitary aspects should be in note when a domestication program is design. They are (a) prevention of pathogens entry by closing culture facilities to the environment, (b) discontinuous (batch) cultured interspersed with disinfection of facilities or following of sites to break transmission cycles, (c) pathogens screening and prevention of movement of infected animals, (d) vaccination and (e) chemotherapy (Kurah and Winton, 2011; Lorenzi et al., 2012).

LIMITATIONS IN DECISION CONTEXT FOR SELECTION *P. pardalis* AS CANDIDATE TO AQUACULTURE

To use any MCDA method (ELECTRE TRI, Weighted Sum, etc), it is necessary to answer for each criterion the following elementary questions: a) how the criterion is measured?; b) Which scale is used (ordinal scale, numerical scale)?; c) What is the semantic associated to each value of the scale? d) The criterion has to be minimize or maximize? Then, considering the problem as an assignment problem, the predefined categories and their limits have to be define. In addition, there needs to define the importance of criteria by association weight to each criterion.

Another gap in scientific knowledge to select *P. pardalis* is the absence of robust and effective methods to integrate all the probabilistic factors that can influence the domestication process. Culture fish has a process of developmental and genetic changes in response to culture (Lorenzen et al., 2012). Therefore, the domestication needs to be understand like a creation of a new open system, with different inputs that fish was subject in wild. The new environmental could affect all the biological organisms, starting news outputs, and the characteristics that was interesting for aquaculture possible could change. Monitoring these aspects is important because the gains made by selection or transgenesis could be not stable along generations or uniform for all species (Devlin et al., 2001).

The domestication of teleost fishes results in changes in many fitness-related traits under intensive aquaculture conditions (Gamperl and Farrell, 2004; Lema et al., 2005). This including the characteristics as reproductive aspects, feeding behavior, schooling behavior, territoriality and aggression (Ruzzante, 1994; Krejszeff et al., 2009; Jonsson and Jonsson, 2006). In addition to these behavioral changes can also result in pronounced changes in both brain and heart morphology (Marchetti and Nevitt, 2003; Pelster, 2003; Mayer et al., 2011) or morphometric differentiation of wild and captivity reared fish (Hard et al., 2000). However, to date, compared to the knowledge on the behavioral, physiological, and morphological consequences of domestication among terrestrial vertebrates, there is very little information how these aquaculture-induced alterations can affect both the production and welfare of intensively farmed fish (Liao and Huang, 2000; Mayer et al., 2011).

The dynamics of the variations of the physiological parameters, sanitary aspects and genetic analyses for detection drifts, mutations, or breed mistakes need to be takes in serious program to selection fish species to be new strains for aquaculture. Russo et al. (2011) proposed excellent method to detect patterns of covariation among rearing parameters and fish quality named self-

Table 4. List of high-priority research areas for domestications programs for L. pardalis as new candidate specie for aquaculture.

Category	high-priority research areas
Market aspects	1. Size market analysis 2. Analysis of *L. pardalis* consumption patterns 3. Good manufacturing practices of the *piracui* 4. Value chain analysis
Biological aspects	1. Nutrition (growth rate, feed conversion, dietary and metabolic requirements of nutrients, optimization of formulations of diets and food management); 2. Limnology (temperature, pH, water hardness great); reproductive aspects (Endocrinology and reproduction biotechnologies applied); 3. Health (epidemiology and mechanism of disease transmission, pathophysiology, immunoprophylaxis and description of therapies with allopathic drugs or natural products, such as medicinal plants), 4. Environmental (environmental impact assessment caused by the possible introduction of *L. pardalis* in other habitats and management of aquaculture effluents); 5. Genetic (breeding and genetic improvement programs, application of DNA-based technologies and genetic manipulation techniques to select phenotypic qualities above).
Economic criteria	1. Net return 2. Production cost 3. Gross revenue 4. Benefit-cost ratio 5. Break even production 6. Risk analysis for capital investment decisions 7. Analyze the economic and social impact of the activity

organization map to establish patterns of occurrence of skeletal anomalies. The molecular analysis by PCR-based techniques restriction fragment polymorphism (RFLP), amplified fragment length polymorphism (AFLP), randomly amplified polymorphic DNA analysis (RAPD), single strand conformation polymorphisms (SSCP), single nucleotide polymorphisms (SNP), simple sequence repeats (SSR) and microsatellites, can solved the technical problems to morphological analysis. This include lacks power for cryptic speciation with homoplastic traits or in species with a large overlap in morphological and meristic traits due convergent selection, factors that could generated problems in genetic background analysis. Multi-locus genotypes of fish by Bayesian methods and hierarchical cluster analysis based on each phenotype and genotype analyses can be used as a tool to monitoring the variations in genetic background (Maes et al., 2006; Corander et al., 2006; Souza et al., 2013).

However, in the best of our knowledge, there are not viable software for monitoring the domestication process and integrating all variables that can interfere in the design of the socio-technical system for conducting the MCDA. New programs of management of this activity should be create with interdisciplinary teams to do interface with natural and social sciences, to consider the context of the appraisal to describe analysis before implementation (Abreu et al., 2001). To maintain a balance between the economy and the ecosystems, based in some excellent reviews writing about this subject like (Liao and Huang, 2000; Fointaine et al., 2009; Lorenzen et al, 2012; Telechea and Fointaine, 2014) and another papers reviewed, we propose a list with high-priority criteria that need to be incorporated in domestications programs, presented at Table 4. We conclude that decision makers, with social responsibility sense, should complete the descriptions of these criteria before selection of *P. pardalis* as fish species candidate for aquaculture.

Conflict of Interest

The authors have not declared any conflict of interest.

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