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ORIGINAL ARTICLE

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Native fish species boosting Brazilian's aquaculture development

Espécies nativas de peixes impulsionam o desenvolvimento da aquicultura brasileira

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Abstract Brazil's aquaculture production has increased rapidly during the last two decades, growing from basically zero in the 1980s to over one half million tons in 2014. The development started with introduced international species such as shrimp, tilapia, and carp in a very traditional way, but has shifted to an increasing share of native species and focus on the domestic market. Actually 40 % of the total production is coming from native species such tambaquí (*Colossoma macropomum*), tambacu (hybrid from female *C. macropomum* and male *Piaractus mesopotamicus*). Other species like pirarucu (*Arapaima gigas*) or surubim (*Pseudoplatystoma* spp.) are considered to have a high production potential. Aquaculture products are mainly market locally. There is still a need to solve technical and financial problems with regards to future aquaculture development. But as species selection to meet the national demand has been concluded there is a big chance that Brazilian's aquaculture development will become a success story.

Keywords aquaculture, Brazil, species, non-native species, development.

Resumo A produção da aquicultura do Brasil aumentou rapidamente nas últimas duas décadas, passando de quase zero nos anos 80 para mais de meio milhão de toneladas em 2014. O desenvolvimento começou através da introdução de espécies internacionais, tais como o camarão, a tilápia e a carpa, de uma forma muito tradicional, mas mudou com o aporte crescente de espécies nativas e foco no mercado interno. Atualmente, 40% da produção total provém de espécies nativas como tambaqui (*Colossoma macropomum*), tambacu (híbrido de *C. macropomum* e macho *Piaractus mesopotamicus*). Outras espécies como pirarucu (*Arapaima gigas*) ou surubim (*Pseudoplatystoma* spp.) são consideradas como de alto potencial para produção. Os produtos da aquicultura são principalmente para mercado locais. Continua a ser necessário resolver os problemas técnicos e financeiros relacionados com o futuro desenvolvimento da aquicultura. Mas, como a seleção de espécies para atender a demanda nacional foi concluída há uma grande chance de que o desenvolvimento da aquicultura brasileira se torne uma história de sucesso.

Palavras-chave aquicultura, Brasil, espécies indígenas, espécies não-nativas, desenvolvimento.

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Introduction

Brazil is a country of continental dimensions, occupying an area of 8,547,404 km². Brazil possesses 12 percent of the planet's reserve of available freshwater, with more than two million hectares of marshlands, reservoirs and estuaries suitable for aquaculture, as well as 25,000 rivers across the country. Brazil has a coastline that stretches for 8,400 kilometers and out of a total of 27 administrative regions: 26 states and the Federal District, 15 of which border the Atlantic Ocean coast.

It was shown that Brazilian aquaculture could be divided in six main sectors, defined by the type of cultured organism being produced (Valentini, 2000). Those sectors are: freshwater fish, marine shrimp, clams, oysters, freshwater shrimp and frogs. Freshwater fish is the only sector present in every state in the country, representing almost 80 percent of total production, followed by freshwater shrimp, which are cultivated in 20 states. All other sectors are restricted to a certain region of the country.

In a review on Brazilians aquaculture (Roubach et al., 2003) was stated the main cultivated species as tilapias (*Oreochromis* spp.), common and Chinese carp (*Cyprinus carpio, Aristichthys nobilis, Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*), followed by pacu (*Piaractus mesopotamicus*), tambaqui (*Colossoma macropomum*), catfish (surubim, *Pseudoplatystoma* sp.), marine shrimp (*Litopenaeus vannamei*) and mollusks (*Crassostrea gigas, C. rhizophorae,*and *Perna perna* (Queiroz et al., 2002).

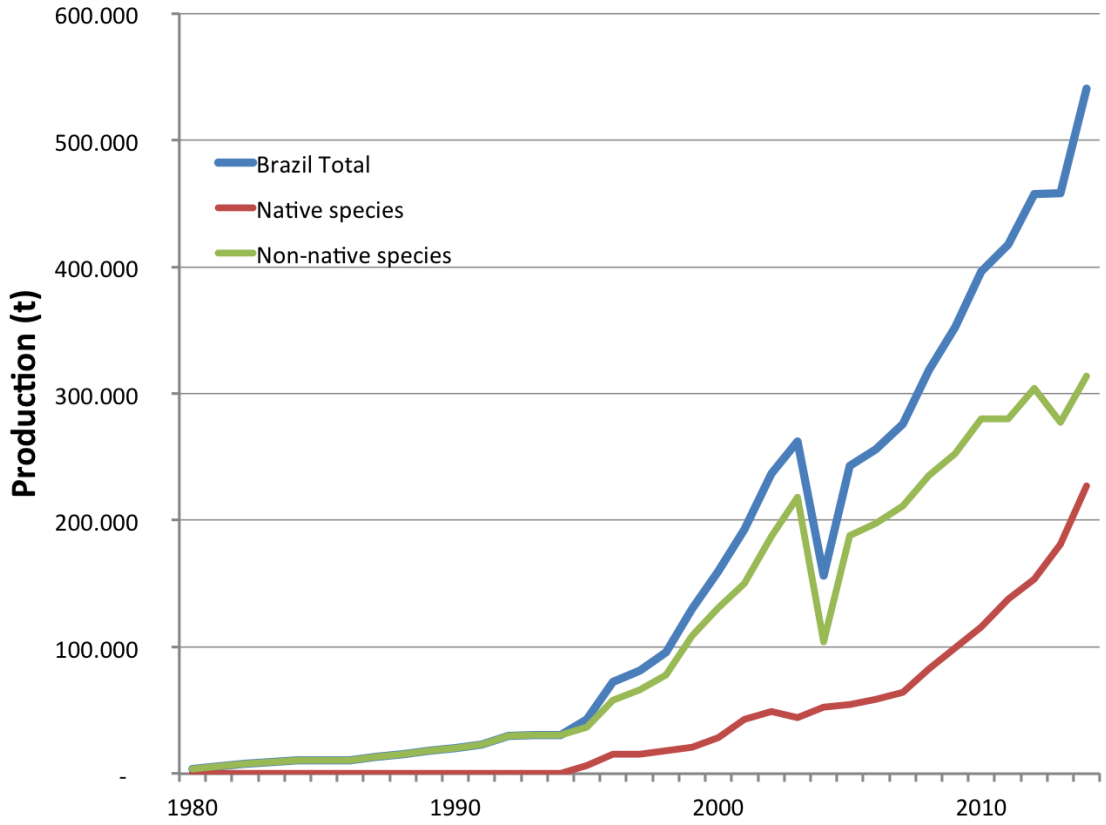

Figure 1 Comparison between total aquaculture production in Brazil and native and non-native species (1980–2014). Adapted from data available from FAO (http://www.fao.org/fishery/statistics/ global-aquaculture-production/query/en).

In Brazil, aquaculture offers the largest potential to increase fish supplies. Aquaculture almost not existed in Brazil in the early 1980s. Following a careful start in the late 1980s, production has increased rapidly from the mid-1990s, passing one half million tons in 2011, making Brazil, according to (FAO, 2015), to the second largest aquaculture producer in the Latin American.

Remarkable the rapid growth in farmed fish production, up from 20,360 tons in 1990 to 159,496 tons in 2000 and up to 540,442 tons in 2014 (Fig. 1). And from this total, 82% come from fresh water aquaculture. The contribution of aquaculture in total fish production was 44 % in 2011.For more detailed information look at Kubitza et al., 2012. They give an in depth analysis of aquaculture production per region showing its huge potential for food production. Fig. 2 gives a more detailed picture on the production of the different species groups between 1980 and 2014.

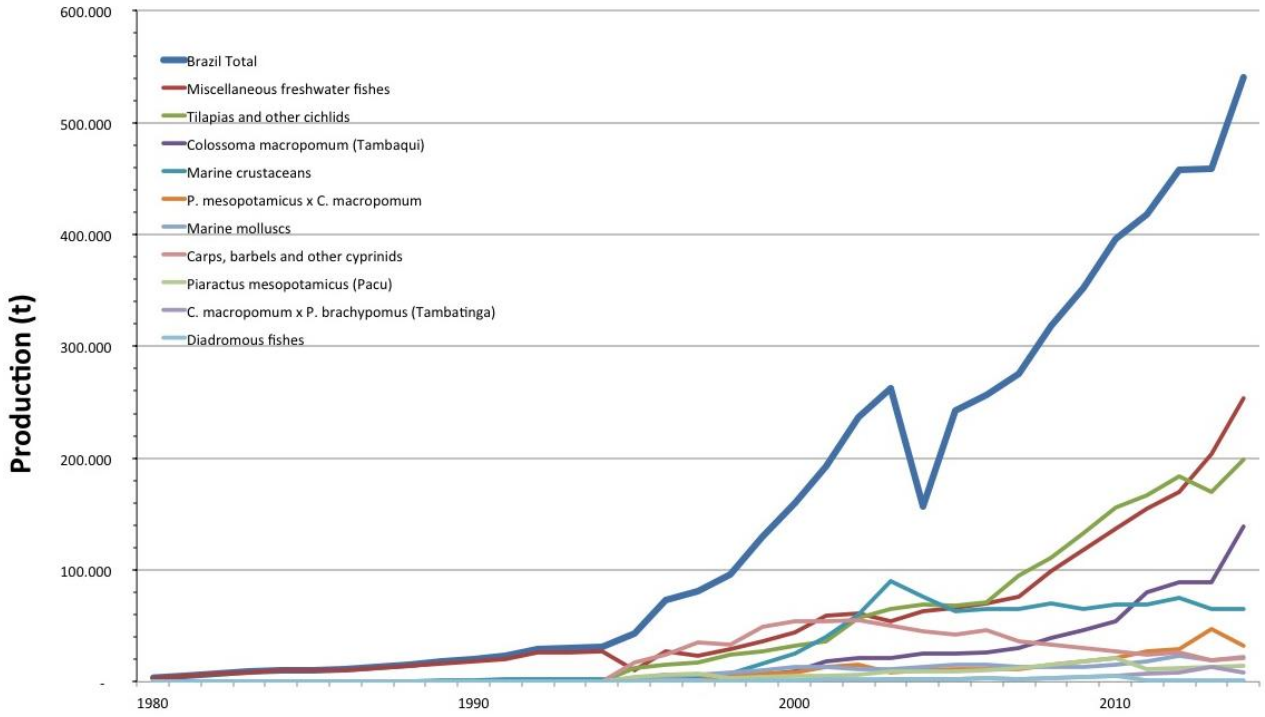

Figure 2 Comparison between total aquaculture production in Brazil and different species groups (1980-2014),Adapted from data available from FAO (http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en).

The aquaculture sector in Brazil has enjoyed very steady long-term growth. In the following we try to estimate the potential on the native species to increase Brazil's aquaculture development.

How it started

Aquaculture development started at the beginning of the last century. The common carp was introduced as early as 1904 in the southern region (Ostrensky et al., 2007), and production is still concentrated in this area mostly due to climatic conditions (SEBRAE, 2012). According to FAO highest production for carps, barbels and other cyprinids of 54,963 tons was recorded for 2002 however, actual figures are much lower (2014: 20,886 tons). Reasons for this decline are unclear.

In 1971 Nile tilapia, was brought from Ivory Coast to the aquaculture research station at Pentecostes, Ceará (Dnocs – National Department of Drought Alleviation). However, by the end of 80's tilapia aquaculture output was still irrelevant. With the adoption of sex reversal technology in early 90's, tilapia aquaculture gained importance, mainly in the south and southeastern states. In 1995, tilapia aquaculture production in Brazil was estimated near 12,000 tons. Major tilapia clusters are located in the State of Western Paraná (pond culture) and in the reservoirs of Northeast and Southeast Brazil (cage culture). In Northeast Brazil major tilapia clusters are found along the course of the San Francisco River (Lakes Sobradinho, Itaparica, Moxotó and Xingó) and the Jaguaribe River (Lakes Castanhão and Orós) (Kubitza, 2016). In 1996 the first introduction of Chitralada strain of Nile tilapia (Thai tilapia) improved the genetic quality of brood stock in many tilapia

hatcheries. The Thai tilapia showed a better growth performance and replaced gradually the non-selected stocks of Nile tilapia. Today Tilapia production in Brazil is the sixth largest in the world (FAO, 2015), and production has expanded all over the country, including the Northeast region. The massive production of male fingerlings, the introduction of net cages, the usage of brood stock with genetic potential, the development of higher quality fish feed, the utilization of larger reservoirs and the supply of high added value products such as fillets have become important factors for the expansion of Tilapia fish farming in Brazil (Kubitza et al., 2012; Prado & Neves, 2015). Actually (2014) production amounts to 198,728 tons. Rabobank expects Brazilian tilapia production to increase by 10 percent a year, surpassing 490,000 tons by 2020 (Fontes & Nikolik, 2015).

The Pacific white shrimp (*Litopenaeus vannamei*) culture began 1972 and has expanded since then, especially in the northeast region, mainly in the States of Ceará, Rio Grande do Norte, Bahia and Piauí. A Brazilian solution with native shrimp species did not reach an economically sustainable level. The production reaches 140,000 tons in 2014with strong oscillations over time because the industry has gone through difficult periods facing challenges such as: diseases, flooding in important production areas. The industry's average production per hectare and year is around 2,000 kg/ha, which by Latin American standards is very high. Most shrimp are produced under semi-intensive conditions Moles & Bunge, 2002). In 2003, intensification was disrupted by outbreaks of the infectious myonecrosis virus (IMNV) and was the reason for the significant overall aquaculture production decrease at that time. But it became now the third most cultured species in Brazil. Native Atlantic shrimp species are of no commercial importance. In Brazil, despite of the presence of few large farms, most of the shrimp farming activity takes places in small and medium sized farms. The farming takes place in ponds and also can be found in low salinity waters (Prado & Neves, 2015).

Mollusk farming was introduced into Brazil in the 1960s but only since 1989 has this activity developed as an important economic alternative for small-scale fishermen. Pacific cupped oyster (*Crassostrea gigas*) is produced in the South region and native oysters species are produced on differing scales in almost every state from the South to the North regions. Scallop aquaculture is a recent activity in Brazil with no commercial farms to date, however, improvements in hatchery seed production of local species indicate that this technology will soon become commercially viable.

The potential for aquaculture on the north and northeast coasts is enormous, especially with seaweed and native oyster production. Seaweed, oyster and crab extraction is a common activity undertaken mostly by women in many fishing communities, in many of these places, aquaculture is providing the first self-employed jobs as it becomes associated with better resource management. Freshwater fish and prawn farms generate more than 100,000 jobs; generally these activities are integrated with other agriculture activities on small scale farming enterprises.

Brazil (540,441 tons) is 12th in the list of the largest fish producers worldwide. Relative to production of freshwater fish, Brazil is the largest power in the Americas (611,343 tons), and its production is approximately 10 times greater than that of Chile (59,527 tons) for this form of culture. In South American continental fish farming, the exotic species Nile tilapia *Oreochromis niloticus*, carp *Cyprinus carpio* and rainbow trout *Oncorhynchus mykiss* are still among the most produced, which is the common scenario throughout the world (Roderick, 2011).

Three decades ago, a first review of the potential of selected South American species for aquaculture purposes was provided, citing certain of these like butterfly peacock bass *Cichla ocellaris*, *Brycon* spp., banded leporinus *Leporinus fasciatus* and black prochilodus *Prochilodus nigricans* having slowly advanced, but others, such as black pacu *Colossoma macropomum* and pirarucu *A. gigas*, have been developing with a promising market, especially in the Amazon region but today almost in the whole country (Saint-Paul, 1986). Other fish (catfish *Pseudoplatystoma* and *Rhamdia*, beyond the characiformes *Piaractus* and *Astyanax*) have gained prominence and are discussed throughout this review.

In Brazil, the most cultivated species are the Nile tilapia and the black pacu; however, the hybrid black pacu x pacu (*C. macropomum* x*P. mesopotamicus*), the common carp, pacu and catfish of the genus Pseudoplatystoma and its hybrids are also worth mentioning (Brasil, 2011). As mentioned,

carp culture in Brazil has declined since 2010 while the production of black pacu and its hybrids has grown considerably.

The data also show that Brazil is the largest importer of fishery and aquaculture products in South America, affirming that despite producing a significant portion of fish when compared to the other countries, Brazil still has a high demand for aquaculture products and thus encourages the domestic growth of farm production (Valladão et al., 2016).

Cultured native species

SERRASALMIDAE

Three species of the family Characidae (subfamily Serrasalminae) are commonly used in aquaculture in Latín America, they are *Colossoma macroponwm* (Cuvier 1818), *Piaractus brachypomus* (Cuvier 1818), and *P. mesopotamicus* (Berg 1895).

The tambaqui (*C. macropomum* (Cuvier 1818)), also known by the names black pacu, black-finned pacu, giant pacu, cachama, gamitana, and sometimes as pacu, is the second largest scaled fish after *Arapaima gigas* (Osteoglossidae) in the Amazon basin, reaching weights of 30 kg in the natural environment (Valladão et al., 2016). It is native to the Amazon and Orinoco River basins. Adult fish feed mainly on fruit and seeds, while juveniles (smaller than 4 kg) feed on zooplankton, insects, snails, and decaying vegetation (Saint-Paul, 1986; Lovshin, 1995; Valladão et al., 2016). Remarkable its adaptation to poor water quality and low oxygen as it has specially adapted lips to gather oxygen rich water from the surface.

The fish has excellent characteristics for use in aquaculture (Saint-Paul, 1986, 1991; van der Meer, 1997), which include reproducing under aquaculture conditions; being low on the food chain; accepting prepared feed; being highly resistant to disease, handling, and poor water quality; having rapid growth; being amenable to high density; having high market acceptability; commanding a high price; and also being marketable as an ornamental fish (Cambos-Baca & Köhler, 2013).

P. brachypomus has the common name of "pirapitinga" in Brazil, but also known as cachama blanca, and paco or pacu in a number of South American countries. It is mainly a herbivorous species but does not have such an restriction to a frugivorous diet like the tambaqui. The largest individuals can weigh up to 25 kg and measure 88 cm.

A taxonomical review of this group, included a third species, *P. mesopotamicus*, commonly known as pacu in Brazil, inhabiting the Parana-Uruguay River system (Britski, 1991). This species is considered to be omnivore, while young individuals usually feed on micro-crustaceans, but adults choose insects and plants, as well as nuts and seeds that fall from trees in flooded forests (Paula et al., 1989). Its medium size is between 3 and 7 kg. It is better tolerant to lower water temperatures than the previous two species. Its preferred water temperature is 26° C.

In addition to that, tambacu (hybrid from female *C. macropomum* and male *P. mesopotamicus*) and tambatinga (hybrid from female *C. macropomum* and male *P. brachypomus*) are new successful aquaculture candidates. Tambacu was created to combine the high growth rate of tambaqui and the cold resistance of pacu.

There was a significant estimation for 2014, accounting a total production of 186.029 tons, compared to 23,584 tons in 2000. This dramatic increase is mainly due to the production of Rondônia and Mato Grosso. Mato Grosso started to implement a strategy of large production sites, taking into account large already existing ponds that permitted the increase of production area with minimum extra investment. In addition, other regions of Brazil expanded its production, such as the States of: Roraima, Tocantins and Maranhão (Prado & Neves, 2015).

ARAPAIMA (*ARAPAIMA GIGAS*)

The pirarucu (*Arapaima gigas*), known as paiche in Peru, is a carnivorous fish from the Amazon basin and is recognized worldwide as the largest continental water fish. It can reach 3 m in length

and up to 200 kg in weight. It is an air-breathing giant fish, which gives him an advantage in oxygen-deprived waters.*Arapaima* is not a mouth brooder, but both parents take care of the offspring for at least one month until the group disperses throughout the lake or pond.

Seed supply relies solely on spontaneous reproduction in in large earthen ponds. Spawning is continuous and some mating pairs can reproduce five to seven times a year. It can reach up to 12 kg in only 1 year. Despite impressive potential for its aquaculture, 2013 estimates for its production reported only 2,300 tons. Due to the low technological levels applied in its captive reproduction, an irregular supply of fingerlings disrupts the whole production chain (Lima, 2015).

PSEUDOPLATYSTOMA SPP.

The Pseudoplatystoma genus includes two species that have been the target of commercial production: the spotted surubim*P. corruscans* and the striped surubim (*P. reticulatum*). However, current production is based on the cultivation of hybrids between these species (*P. corruscans* x *P. reticulatum*) or other South American catfish such as *Leiarius marmoratus* or *P. tigrinum*. These fish are carnivorous with large flattened heads, and the main differences are the marks on the skin, with shaped spots on spotted surubim and traces shaped in the striped surubim. They reach market size of up to 2 kg after 1 year of cultivation. Cultivation details are summarized by (Goulding & Carvalho, 1982). It is the high productive potential and quality of meat that boost interest in these species, which are classified among the most commercially valuable fish (Crepaldi et al., 2006).

Discussion

Brazil pioneered the induced spawning of freshwater and marine fish using hypophysation techniques several decades ago (Ihering, 1937). Much progress has been made since then, especially in freshwater aquaculture of tilapia and carp, two species of major impact in Brazil's aquaculture development in the past. These species were used because of their easy cultivation, the presence of technologies and well-established management techniques (Paula et al., 1989).

Further introductions of exotic species continued. The bullfrog (*Rana catesbeiana*) was introduced in the 1920s. In the 1930s, various fish species were introduced, including channel catfish (*Ictalurus punctatus*), rainbow trout (*Oncorhynchus mykiss*), and several tilapia species (*Tilapia* and *Oreochromis* spp.). In the 1940s, it was the black bass (*Micropterus salmoides*), and in the 1950s, Chinese carps - grass, silver, and bighead (*Ctenopharyngodon idella, Hypopthalmichthys molitrix* and *Aristichthys nobilis*) (Zimmermann & Benetti, 2001). Nile tilapia (*Oreochromis niloticus*), several species of marine shrimp (*Litopenaeus* spp.), and the freshwater prawn (*Macrobrachium rosenbergii*) were introduced in the 1970s. Then followed the African catfish (*Clarias gariepinus*), Japanese oyster (*Crassostrea gigas*), Pacific salmon (*Oncorhynchus* spp.), Atlantic salmon (*Salmo salar*), and American crayfish (*Procambarus clarkii*) during the 1980s.

However, the focus of Brazilian's aquaculture changed as noted by (Pinciato & Ascvhe, 2016). He observed an increasing share of native species in Brazil's aquaculture production, as is demonstrated in Fig. 3. Until the mid of the 90's aquaculture was based a 100 % on non-native species. Later on the importance of native species increased to an actual contribution of 40 % on the total aquaculture production.

On the other hand, despite the rich diversity of South American fish, knowledge of the biology, reproduction, nutrition and domestication was slower for native species. By the end of the 70th, first studies on biology and ecology of native (fish) species, especially from the Amazon but as well from the Paraná and São Francisco Basins, appeared and preliminary experiments on their suitability of aquaculture purposes were conducted.

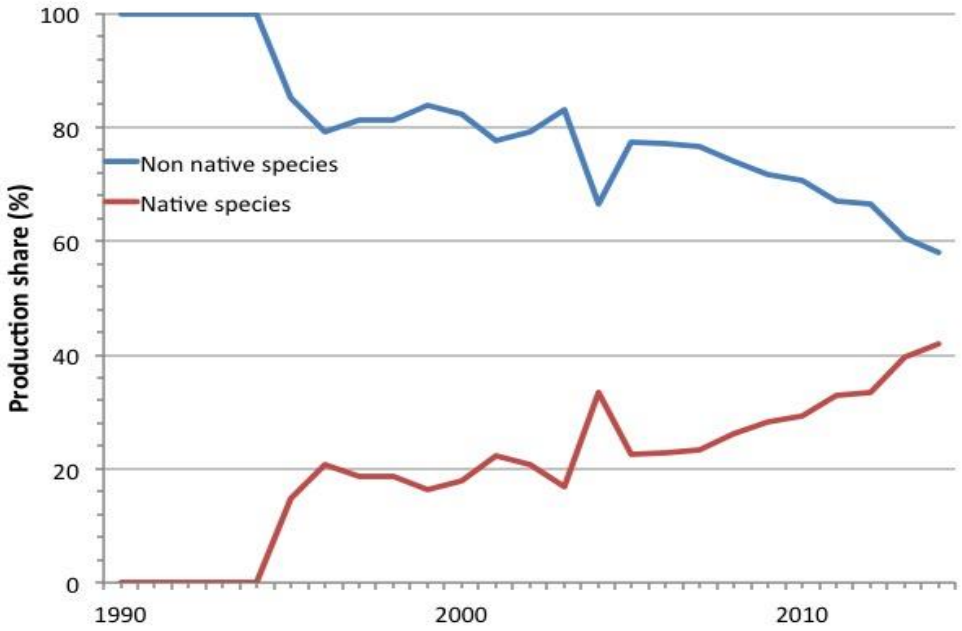

Figure 3 Comparison between production share of native and non-native species to aquaculture production in Brazil. Adapted from data available from FAO (http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en).

At that time public became alerted about the ecological impact of invasive species. Non-native invasive fish species are increasingly recognized as a significant contributor to extinction threat in fresh and marine environments, one that joins and combines synergistically with habitat loss and fragmentation, hydrologic alteration, climate change, overexploitation, and pollution. Although not all introduced fishes become established, and the fraction of those that do often have little appreciable effects on their new ecosystems, many others exert significant ecological, evolutionary, and economic impacts (Cucherousset & Olden. 2016).

In the late 1980s, the pacu (*P. mesopotamicus*), the tambaqui (*C. macropomum*), and their hybrids (tambacu and tambatinga) were considered by Brazilian researchers as the best candidates for aquaculture. In the early 1990s, some farmers began producing additionally new species such as pirapitinga (*P. brachypomus*); matrinchã, piracanjuba and piraputanga (*Brycon* spp.); curimatã, curimbatá and curimba (*Prochilodus* spp.); and piaus (*Leporinus* spp.) at different levels of intensity.

Production in Brazil is expected to increase with 68% by 2021, due to significant economic investments in the sector (OECD, 2015). The access to water resources in Brazil is considered to be excellent. The country has more than 8,400 km of coastline, 3.5 million hectares of public dams, 5 million hectares of private dams. The production shift from non-endemic to native species will for sure will increase the acceptance from the local population. However, due to increasing import of salmon from Chile and pangasius from Vietnam Brazil's aquaculture industry will face serious import competition (Pincinato & Asche, 2016). However, the use of native species is a development path that can be better suited to local ecosystems as well as local markets.

In a detailed study about the consolidation of a sustainable aquaculture development the following main problems, which are more of technical and financial nature, were summarized (Ostrensky et al., 2008):

- Technical problems: a lack of training and technical qualification in the aquaculture productive chain.
- Economic/administrative problems: the difficulty of access to credit for investing and funding aquaculture.
- Political/administrative problems: the lack of public policies for the development of the activity.

The actual political and economic situation of Brazil will not facilitate the solution of these problems. But the decision which species should be selected for future aquaculture development has been made. This will be a big chance for Brazil's aquaculture development.

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