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Biology of black bass *Micropterus salmoides* (Lacepède, 1802) fifty years after the introduction in a small drainage of the Upper Paraná River basin, Brazil

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ABSTRACT

Garcia DAZ, Costa ADA, Leme GLA, Orsi ML. 2014. Biology of black bass Micropterus salmoides *(Lacepède, 1802) fifty years after the introduction in a small drainage of the Upper Paraná River basin, Brazil. Biodiversitas 15: 180-185.* The dispersion of organisms by human actions has been the major source of changes in the natural distribution of species, making the introduction of non-native species a threat to biological diversity. *Micropterus salmoides* is a fish originating from North America, which was introduced in a lagoon in the Ecological Park of Fazenda Monte Alegre in southern Brazil over 50 years ago. The reproductive activity, weight-length relationship and relative condition factor were analyzed to evaluate the health parameters of the species. The result allows us to classify the reproductive activity of this population as moderate. It was found that the health condition patterns are identical to those theoretically expected. The occurrence of individuals downstream of the lagoon shows that the population has been presenting dispersion conditions to new environments, posing a threat to local biodiversity. Management measures, such as isolation or eradication of the population, are required to control the species within the studied site, and prevent its dispersion into natural watercourses.

Key words: Centrarchidae, dispersion, introduction of species, non-native species, Tibagi River.

INTRODUCTION

The accidental or deliberate introduction of non-native species, generally for economic purposes, never considering the possible ecological impacts (Vitule 2009), is one of the major global changes caused by man's actions over the centuries. In aquatic environments, the introduction of non-native fish can cause trophic changes to the habitat and to the community, leading to hybridization, loss of genetic diversity, as well as to the introduction of pathogens and parasites (Delariva and Agostinho 1999), thus representing a human activity of great risk to biological diversity (Enger et al. 1989).

Micropterus salmoides (Lecepède 1802), a member of the order Perciformes, family Centrarchidae, is a fish species native to North America popularly known as black bass or largemouth bass. This species is naturally distributed in the area between the Hudson Bay basin and the St. Lawrence-Great Lakes basin to the Mississippi River basins, and the Atlantic drainages from North Carolina to Florida and northern Mexico (Page and Burr 1991). Found in slow flowing environments and turbid waters of rivers and lakes (Tomerelli and Eberle 1990), the adult *M. salmoides* is a top predator in the aquatic ecosystem. When juvenile, it feeds on zooplankton, insects and other invertebrates, and during adulthood, preys on crustaceans, fish and other invertebrates (Hickley et al. 1994; García-Berthou 2002). In its place of origin, its maximum recorded length is 97 cm (Page and Burr 1991) and its maximum mass, 10.09 kg (Tomelleri and Eberle 1990).

This species was introduced in many countries, such as Portugal (Colares-Pereira et al. 1999), Spain (Elvira and Almodóvar 2001), Italy (Orrù et al. 2010), Czech Republic (Musil et al. 2010), Kenya (Britton and Harper 2006), Mozambique (Weyl and Hecht 1999), Japan (Takamura 2007), and South Korea (Lee et al. 2010), due to its qualities, which make it suitable for sport-fishing. In Brazil, *M. salmoides* was introduced in Belo Horizonte, in 1922, for aquaculture purposes. Nowadays, it is distributed through artificial systems, such as lagoons and semi-natural reservoirs, from Rio de Janeiro to Rio Grande do Sul (Schulz and Leal 2005).

Many invasions have resulted in the establishment of predator populations in many regions, which can have an impact on native fish populations through predation pressure (Gratwicke and Marshall 2001). Based on these facts, a list of the 100 worst invasive species in the world was elaborated, including the *M. salmoides* among the invasive alien species (Lowe et al. 2000).

This paper aims to characterize the biology of a population of *M. salmoides* introduced in Brazil grounded in information about its health condition and reproductive activity, and also evaluate the evidence of dispersal from the study site.

MATERIALS AND METHODS

The Ecological Park of Fazenda, Monte Alegre, Brazil was established in 1980, in an area of 11,116 ha, owned by the company Klabin S.A., a manufacturer of wood pulp and paper products. Located within this area is the João Pinheiro Stream, a subaffluent of the Tibagi River, Upper Paraná River basin. The introduction of *Micropterus salmoides* at this location occurred in the 1950s, where a self-sustaining population was established. Samplings were accomplished in this area from 12 to 16 March 2012 and 11 to 15 March 2013. Due to restrictions in the collections in the Ecological Park, this was the period for which sampling was authorized. Two sampling collection points established, one at the impoundment (Point 1) and the other downstream of it in a lotic stretch of the João Pinheiro Stream (Point 2) (Figure 1).

The impoundment, whose ravine harbors a riparian forest of secondary composition, has semi-lotic characteristics. The environment is eutrophic, has low transparency, with algae and macrophytes on the surface and a silty bed. Its average width is 40 m and its depth ranges from 0.82 to 2.4 m. The stream is mostly a lotic environment with a bedrock and high transparency. Its width varies from 3.94 to 4.49 m and its depth ranges from 0.21 to 0.31 m. The average altitude is 885 m; the climate is subtropical with an average temperature of 16.3 ºC in winter and 23.2 ºC in summer; with an average annual rainfall of 1,478 mm (Reis et al. 2006).

The sample collection was accomplished using drag nets, trawls, sieves and fishing with artificial baits. In point 2 were not used the artificial baits. A period of two hours was established for each point, along an extension of 30 m at point 1 and 100 m at point 2. The variation in the capture methods occurred to include all size classes of fish and according to the characteristics of each point.

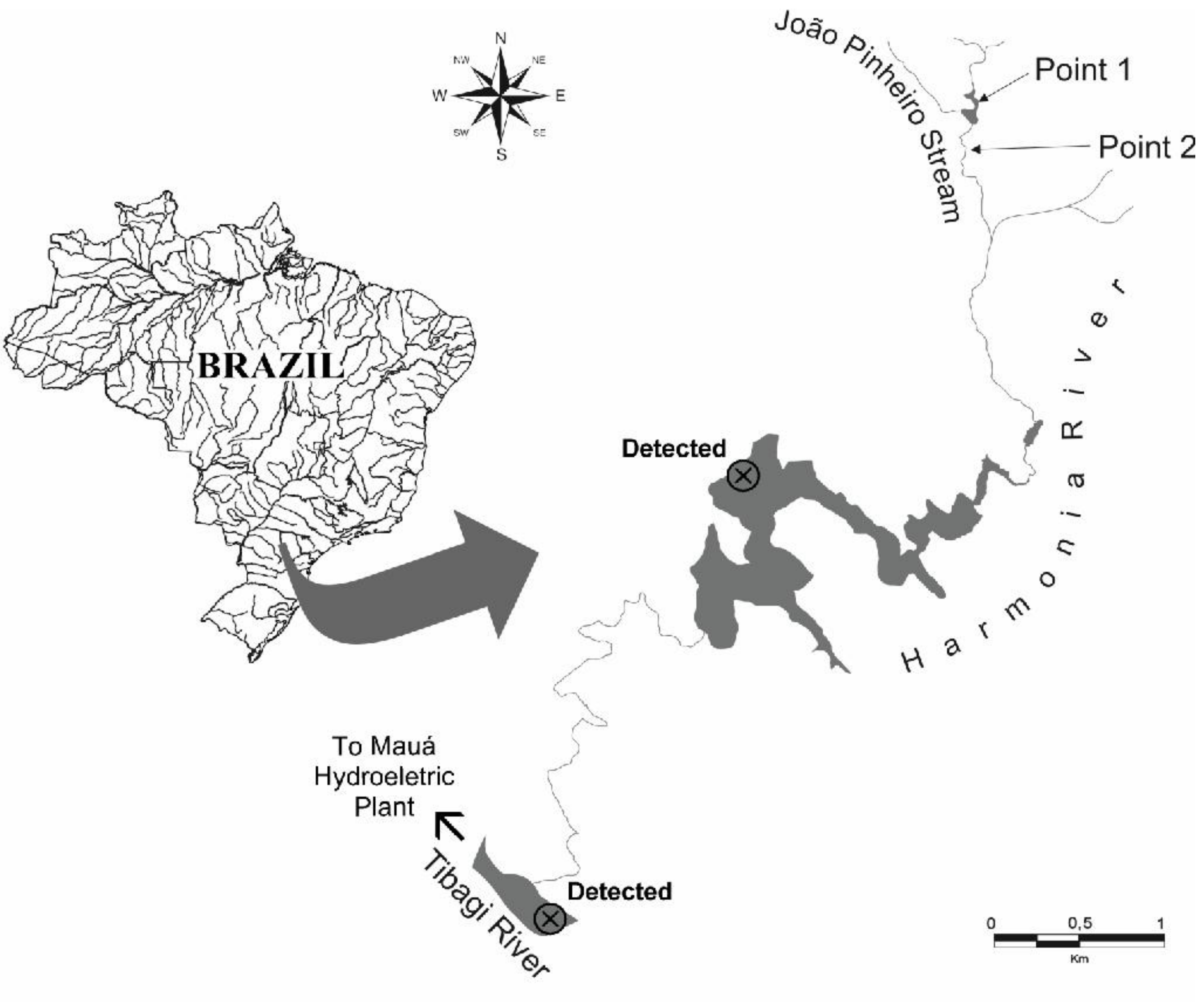

Figure 1. Location of João Pinheiro Stream, subaffluent of the Tibagi River indicating the sampling sites of *Micropterus salmoides*: point 1 (24º16'58.96"S, 50º35'00.04"W), point 2 (24º17'04.49"S, 50º34'58.71"W); and the detected sites.

The animals collected were exposed to anesthetic benzocaine until death and the biometry of the individuals was obtained immediately after the animals were fished considering the total length of the samples (Lt, to 0.1 cm) and the total mass (Wt, to 0.1 g). Later, a ventral incision was performed to remove the stomach and the gonads to determine the sex of the individuals. The fishes were fixed in 10% buffered formalin with calcium carbonate. After 48h, they were transferred to 70% ethanol and then deposited in the ichthyological collection of the Museum of Zoology, State University of Londrina (MZUEL 6507, 6508).

Analyses of the status and trends of introduced species are important to understand their dynamics and implement possible management measures (Gomiero et al. 2008). In this regard, the mass-length relationship is a quick and easy way used to describe the growth without considering the fish age (Gomiero et al. 2010). The determination of the mass-length relationship in fish can describe the structural characteristics of individuals within the population (Benedito-Cecílio and Agostinho 1997). This ratio was obtained using the relationship between the mean total mass (Wt) and the total length (Lt) of the individuals and is expressed by the equation: $Wt = \Phi. Lt^{\theta}$ (Wt = total mass of individuals; Φ = linear coefficient; Lt = total length of individuals; θ = angular coefficient (constant related to the type of growth of individuals) (Barbieri et al. 1981). If $\theta = 3$, the allometric growth is isometric, this means that the increase in mass follows the increase in length; if $\theta > 3$, positive allometric grow, means that there is an increase in mass greater than in length; and if $\theta < 3$, negative allometric grow, and there is an increase in length greater than in mass.

The relative condition factor (Kn) is obtained from the mass-length relationship and used to determine the condition of health, *i.e.*, the state of well-being of the fish and that reflects the recent nutritional status, independent of the species. The ratio is obtained between the total mass observed and the mass theoretically expected for a given length (Kn = Wt / We). It is considered, as defined by Le Cren (1951), where, Wt = total observed mass of the individual; We = total expected mass of the individual: $We = \Phi. Lt^{\theta}$ (θ = angular coefficient obtained from the mass-length relationship). The mean value was calculated and then compared to the standard value Kn = 1.0 by the Student's "*t*" test ($p < 0.05$).

The frequency of occurrence of feeding (FOF) assesses the percentage of stomachs in which a particular food item is found in relation to the total number of stomachs analyzed for each sampling point. The stomach contents were analyzed under a stereo microscope and food was identified to the most detailed taxonomic categories. Food analysis was accomplished using the Amundsen graphic method (Amundsen et al. 1996) using prey distribution, prey-specific abundance and frequency of occurrence.

For the following analyses, only adult individuals were considered. For the provision of values for the analysis of the gonad somatic index (Ig), the gonad mass of each individual was calculated in grams (Wg) using the equation: Ig = Wg.100/ Wt (Wg = mass of the gonad, Wt = total mass) (Vazzoler 1996). The reproductive activity index (RAI) proposed by Agostinho et al. (1993) was estimated based on the Ig data. According to the RAI results, the reproductive activity can be classified as incipient ($0 \geq$ RAI <5), moderate (≥ 5 RAI <10), intense ($10 \geq$ RAI ≤ 20), and very intense (RAI ≥ 20).

RESULTS AND DISCUSSION

Eighty-one (81) specimens of *M. salmoides* were captured and analyzed. Among those, 20 females and 24 males were collected from point 1, and four females, three males and 30 immature individuals, from point 2.

The analysis of the mass-length relationship revealed a linear coefficient (Φ) value of 0.01 and an angular coefficient (θ) value of 3.01, characterizing an isometric growth, that the increase in mass followed the increase in length. The mass-length relationship, linear regression with the plotted pairs of data, equation and value of the determination coefficient (R^2) are shown in Figure 2(a). It was found that, on average, the degree of healthiness was equal to that theoretically expected (Kn = 0.99 ± 0.13 (0.63-1.50), p = 0.56) [Figure 2(b)].

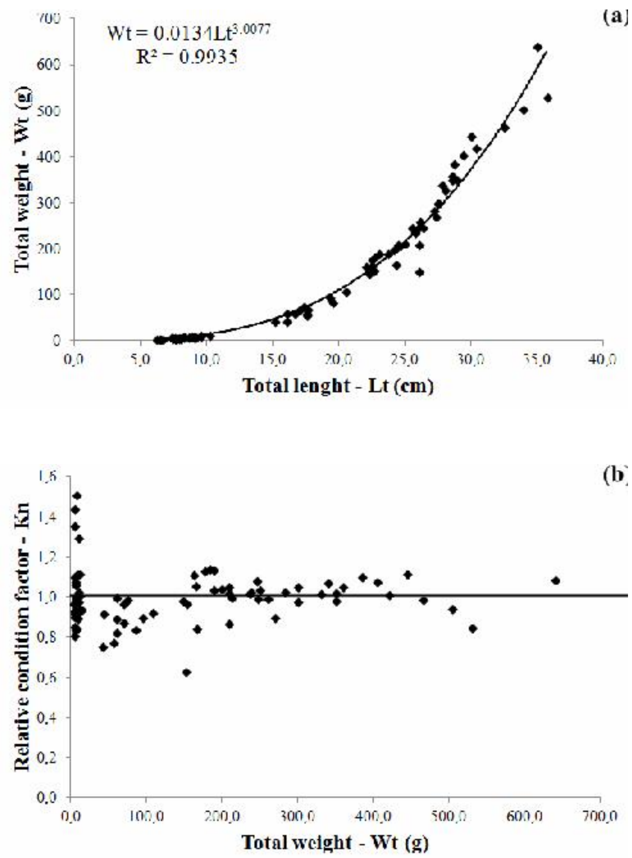

Figure 2. A. Mass-length relationship curve for *Micropterus salmoides*; B. Variation of the relative condition factor values (Kn) compared to the standard value (Kn = 1.0) in relation to the total mass (Wt).

Table 1. Frequency of occurrence of feeding for categories consumed by 81 individuals of *Micropterus salmoides*. DR0: Stomach degree of repletion.

Food categories	**Point 1 (*n* = 44)**	**Point 2 (*n* = 37)**
Crustacea	13.33	5.27
Insecta	31.67	23.68
Plant material	11.67	0.00
Fish	8.34	5.27
Unidentified	25.00	13.15
DR0	10.00	52.63

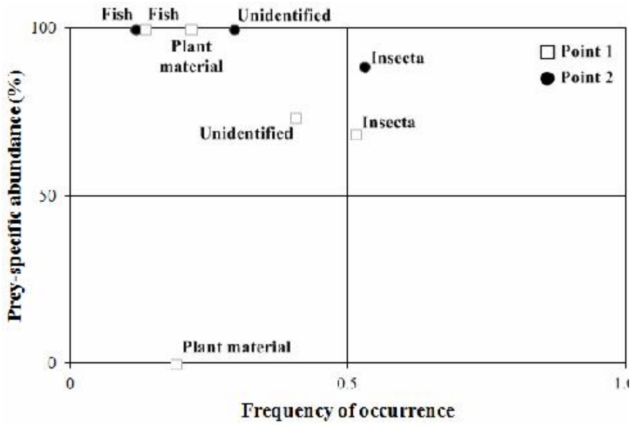

Figure 3. Graphic representation of prey-specific abundance in function of the frequency of occurrence of the food categories registered in the gastric contents of *Micropterus salmoides*.

Analysis of the frequency of occurrence of feed revealed five food categories: Crustacea, Insecta, Plant Material, Fish, and Unidentified due to advanced state of digestion (Table 1). The most frequent food categories during the sampling period were Insecta and Unidentified in point 1, while in point 2, approximately 53% of the stomachs of the individuals were empty (Figure 3).

Among the fish that had their sex determined, 47.06% were females, while males predominated with 52.94%. The reproductive activity index (RAI) value was 8.08 (Ig = 0.58). This enabled the demonstration that the population in the impoundment had a moderate reproductive activity during the sampling period.

The survival of the species in different areas depends on the environmental adaptability, which exerts an influence on feeding and reproductive events throughout the life cycle of the species (Gomiero et al. 2010) in such a way that changes in the condition factor may be related to the characteristics of each environment (Le Cren 1951). The mass-length relationship and relative condition factor of introduced species vary with the time of introduction, population size, environmental characteristics, intra-and interspecific interactions, and sexual maturity (Gomiero et al. 2008). Outside their original range in North America, this species does not reach the same maximum size and age, but in a lake in Kenya, equatorial climate, the growth is faster (Britton et al. 2010). This rapid growth can be attributed to the warmer conditions of the water in this environmental receptor, which in turn optimize the species feeding, growth and reproduction (Hickley et al. 1994, Britton et al. 2010). Established populations of introduced fish can alter the energy flow of an ecosystem by filling unoccupied ecological niches, thereby competing with native fish (Scott and Helfman 2001) and presenting trophic adaptability in response to changes in prey availability (Nobriga and Feyrer 2008).

Micropterus salmoides, an almost exclusively piscivorous species (Keast 1985), is a top predator of the North American aquatic ecosystem (Heidinger 1975). However, after more than 50 years of introduction into the point 1, this fish began to prey on available food resources. Insecta was the dominant food category in the diet of fishes, and, according to the graphical method of Amundsen et al. (1996), the species tended to specialize in their food preferences. On the other hand, some individuals fed on crustaceans and fish, which are items with high abundance and low frequency of occurrence. As for the plant material found in the stomachs, this type of food must have been eaten on an occasional basis, since preys, such as insects and crustaceans, are housed in aquatic plants. It is possible to infer that in the early years of introduction occurred intense piscivory at point 1, and consequently, a reduction in richness and abundance of native fish. In the studied impoundment, no other fish species were collected, and only the common carp *Cyprinus carpio* Linnaeus 1758, another introduced species, was detected (personal observation). With the decrease of fish, this population acquired preference for insects. His intense piscivory, which seems to occur in the early years of introduction, can endanger the maintenance of the fish diversity. In the Tibagi River basin new species have been described, particularly in small watercourses. As an example, we emphasize the new armored catfish, *Otothyropsis biamnicus* (Calegari et al. 2013), whose type locality is the Harmonia River.

The occurrence of individuals downstream of the impoundment suggests that this species encounters favorable conditions for the dispersal of young individuals into new environments of the hydrographic basin. This is substantiated by the fact that the thirty individuals sampled in the stream did not yet present the first gonad maturation, *i.e.*, they were immature. Even having observed displacing movements downstream of the impoundment, it is not possible to affirm that the specimens of *M. salmoides* have been finding favorable conditions for their establishment in this downstream environment, due to their small size, as well as to the small number of captures of adult individuals.

It is worth considering that the João Pinheiro Stream belongs to the Tibagi River drainage, whence escapes of *M. salmoides* from fish farms have occurred, as reported by Orsi and Agostinho (1999). It is likely that this species has reached the self-sustaining population conditions in the point 1 becoming able to offer a propagule pressure in the basin. The existence of viable populations in restricted areas can act as propagule pressure points that may favor the initial population to become invasive to the basin (Simberloff 2009).

Several authors have reported successful invasions of *M. salmoides*, as well as damage to the biota at the sites of invasion. The presence of established populations of this species in Africa caused a striking decrease in fish diversity on the sites (Britton and Harper 2006). The introduction of this species in the European Continent occurred in the mid-nineteenth century, and since then it is considered established in various watercourses (Musil et al. 2010). Lee et al. (2010) recorded its introduction in Asia in 1973, which significantly affected the diversity of native fish species.

In Brazil, the number of fish species described has increased significantly every decade, mainly due to the discovery of small species, which are often confined in smaller watercourses. The Varanal Stream, near the João Pinheiro micro-basin, has 15 identified species. This is a relatively high number for the nearby streams (Shibatta et al. 2008). Point 1 is located 8 km from the Tibagi River. Among them, there is another artificial system (Figure 1), in Harmony River where there is occurrence of adults of *M. salmoides* (Vitule et al. in prep.). Further, downstream of this area, is the dam of the Mauá hydroelectric plant, reservoir where also has been detected the specie (Fishermen Association of Telêmaco Borba, personal communication). Its reservoir can further intensify the problem, as these artificially flooded areas facilitate the introduction and establishment of species (Johnson et al. 2008). Thus, it is possible that individuals of *M. salmoides* disperse to other streams of the Tibagi River basin, due to the facilitation brought about by the reservoir. If this occurs, the inventory and knowledge about the dynamics of these streams environments may be impaired due to alterations and impacts caused by the species.

The isometric growth, good degree of healthiness, moderate reproductive activity and displacement of *M. salmoides* juveniles downstream of the lagoon suggest that this species found favorable conditions for its establishment on the site and that there is a considerable risk that this species will become invasive to the basin. The risk of invasion of non-native species present in the Upper Paraná River basin was assessed and *M. salmoides* was classified as a species with a moderate risk of invasion, and its use and maintenance in Brazil was regarded as ecologically unwise (Britton and Orsi 2012).

This information will support actions to contain population invasions, confining them to their place of occurrence, thus preventing their dispersion or, if possible, taking measures for their eradication (Copp et al. 2005; Britton et al. 2011).

CONCLUSION

It was found that the health condition patterns are identical to those theoretically expected. The occurrence of individuals downstream of the lagoon shows that the population has been presenting dispersion conditions to new environments, posing a threat to local biodiversity. Management measures, such as isolation or eradication of the population, are required to control the species within the studied site, and prevent its dispersion into natural watercourses.

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