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Article

Status of the Invasion of a Poaceae Species in Tropical Semiarid Reservoirs

Status da Invasão de uma Espécie de Poaceae em Reservatórios do Semiárido Tropical

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ABSTRACT - The species of the *Urochloa* genus, exotic and infesting in Brazilian waters, are known to be invasive and dominant, occupying from humid, shallow areas, and irrigation canals to margins of deep reservoirs. This paper hypothesis that less depth reservoirs have higher infestation rate and higher biomass of *U. arrecta*. The objectives were to measure the percentage of occurrence of exotic macrophyte *U. arrecta* in 40 ecosystems from the Mamanguape basin (Paraíba, Brazil) and determine the infestation of the species in two reservoirs. The acquired data were geo-referenced with the ArcGIS software (v. 9.3). A covariance analysis was performed using the R program (The R project is Statistical Computing). The results showed large spatial distribution of the species, indicating that reservoirs may act as stepping-stones in the landscape, in a regional scale. The hypothesis of biotic acceptance is seen as a relevant factor in explaining the presence of the species with low percentage of occurrence in 37 out of the 40 sampled ecosystems, being observed only in areas prone to the colonization of native and naturalized macrophytes, in banks and points of lower declivity, in both spatial scales studied. Thus, factors such as environmental instability (promoted by intermittent or prolonged desiccation of the habitat), shadowing and declivity of the reservoirs synergistically acted on exotic and native species.

Keywords: *Urochloa arrecta*, aquatic ecosystems, spatial scales.

*RESUMO - Espécies do gênero **Urochloa**, exótica e infestante em águas brasileiras, são reconhecidamente invasoras e dominantes, ocupando desde áreas úmidas e rasas, canais de irrigação a margens de reservatórios profundos. Hipotetiza-se neste estudo que reservatórios com menor profundidade apresentam maior taxa de infestação e maior biomassa por **U. arrecta**. Os objetivos foram mensurar o percentual da ocorrência da macrófita exótica **U. arrecta** em 40 ecossistemas da bacia do Mamanguape (Paraíba, Brasil) e determinar a infestação da espécie em dois reservatórios. Os dados obtidos foram georreferenciados com o programa ArcGis (v. 9.3). Análise de covariância foi realizada, utilizando-se o programa R (The R project for Statistical Computing). Os resultados mostraram ampla distribuição espacial da espécie, indicando que reservatórios podem atuar como "stepping-stones" na paisagem, em escala regional. A hipótese da aceitação biótica é apontada como fator relevante para explicação da presença da espécie com baixo percentual de ocorrência em 37 dos 40 ecossistemas amostrados, sendo observada apenas em áreas propensas a colonização de nativas e naturalizadas, em margens e pontos de menor declividade, em ambas as escalas espaciais estudadas. Dessa forma, fatores como instabilidade ambiental (promovida pela intermitência ou dessecação de habitat prolongada), sombreamento e declividade dos reservatórios atuaram sinergicamente sobre exóticas e nativas.*

Palavras-chave: *Urochloa arrecta*, ecossistemas aquáticos, escalas espaciais.

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INTRODUCTION

Urochloa is a well distributed genus worldwide, and it is considered infesting in many parts of the world, including in Brazil. The *Urochloa arrecta* species, belonging to the Poaceae family, formerly described as *Urochloa subquadripara* (Thomaz et al., 2009a; Michelan et al., 2010; Alves and Barbosa, 2013), is from Africa, and it is perennial, infesting and common in several humid ecosystems (Pott et al., 2011; Wipff and Thompson, 2014). The species presents high efficiency in the use of resources, fast growth and resistance to temporary floods (Kissmann, 1997; Thomaz et al., 2009a, b). It was initially introduced by the forage potential, being considered toxic for bovine (Pott and Affonso, 2000), and it rapidly became a serious problem in continental waters.

Previously described in South and Southeast states of Brazil, the current distribution of the genus in Brazil was increased by new descriptions and registrations in several regions. Some species of the *Urochloa* genus, identified as present in Brazilian northeastern waters, are classified as invaders and dominants in deforested and humid areas, obstructing small courses of water, reducing water quality and promoting modifications in the compositions and distribution of the water fauna (Leão et al., 2011).

One of the central issues of the processes of biological invasion in aquatic ecosystems is the compromise of multiple uses and of the biodiversity by the excessive growth of the populations. Changes in the communities of native species is commonly associated to the formation of exotic macrophytes populations with high density, distributed in monospecific banks in rivers, margins of supply reservoirs, flooded rice areas and irrigation canals (Mormul et al., 2010; Carniatto et al., 2013). Thus, the reduction of the richness of native species may occur due to the biotic interactions with exotic macrophytes, such as interspecific competition and, consequently, competitive exclusion (Thomaz et al., 2009b). The availability of resources and the degree of natural and/or anthropogenic perturbation are potential influencing factors in the invasion processes (Souza et al., 2009).

The reservoirs proportionate new possibilities for colonization and propagation of invader species (Havel et al., 2005). Considered landscape units and inserted in the influence area of the same drainage basin, they present a spatial and functional dependence on the influence area, associating themselves to the ecological processes. In this context, human manipulations in the landscape, such as construction of reservoirs and dams, in addition to changing the landscape, interrupt the connectivity of ecosystems and act as a bridge for the dispersion of exotics, although this former role is not well explained (Havel et al., 2005; Johnson et al., 2008). Theoretical and observational studies indicate relative success of exotic species in thinner scales and the evident paradox, evidenced in experimental studies, of the positive association between native and exotic species in large scales and negative in restrict scales (Fridley et al., 2007).

In the Northeast region, the irregularity in the space time distribution of the pluviometric precipitation is recognized as an influencing factor of the dynamic of the reservoirs and dams, whereas this irregularity in Paraíba is responsible for the classification of almost the entire surface of the State (94%) in the semiarid region (Maltchik, 2000). In this context, the upland forest (brejo de altitude), considered humid exception areas, isolated in the semiarid zones of the Northeastern sertão and agreste, are excepted (Andrade-Lima, 1982).

Considering the low knowledge regarding the distribution of *U. arrecta* in the Northeast region and the invasion potential of the species in aquatic ecosystems, this paper sought to determine the occurrence percentage of the *U. arrecta* exotic macrophyte in 40 ecosystems in the Mamanguape basin (Paraíba, Brazil) and the infestation of the species in two upland reservoirs. The hypothesis is that the reservoirs with less depth present a higher rate of infestation and higher biomass of *U. arrecta.*

MATERIAL AND METHODS

Study area

The drainage basin of the Mamanguape river is located in the extreme east of the State of Paraíba (Brazil), occupying an area of 3,522.69 km² (Executive Agency for Water Management –

"AESA", 2003), anthropized and with high levels of human occupation and economic activities developed around the aquatic bodies. Two different reservoirs, belonging to the Mamanguape basin and located in areas recognized as "Upland Forests (brejos de altitude)", "islands" of humid forest, established in the semiarid region, surrounded by Caatinga vegetation (Andrade-Lima, 1982), were chosen for the comparative study. The Vaca Brava supply reservoir (S 06°59'09.8"/ W 035°45'09.9"), with capacity for 3,783,556 m³ (AESA, 2013) is a deep environment (around 25-35 m deep), located in an Ecological Reserve area, surrounded by secondary riparian vegetation of regeneration. On the other hand, Rio do Canto (S 06°57'04.2"/ W 035°42'31.8") is a shallower supply reservoir (4 m deep), with elevated level of disposal of domestic effluents, and, in some margins, secondary riparian vegetation.

Sampling

The sampling was initiated with the collection and registration of occurrences and intensity of the *Urochloa arrecta* infestation along the Mamanguape river basin, covering 40 reservoirs in the basin influence area.

The geographic position of each sampling point was obtained by GPS. The sampling was performed by visualization of the margin and with a boat in slow movement, thus obtaining the registry of the presence or absence of the *Urochloa arrecta* in the studied ecosystems. In environments in which the presence of the macrophyte was registered, the measurement of the maximum length, width and profundity of the macrophyte banks was performed, with rulers manufactured with graduated PVC pipes (precision of ± 0.5 m).

The maximum length of the banks was obtained by positioning the template over the banks, from the margin to the maximum coverage point; the maximum width, in meters, was measured by means of horizontal positioning of the template, parallel to the margin. The depth of the sampling local was estimated with the template on the vertical, inserted until the bottom of the reservoir.

The 40 reservoirs were visited at least once, and the visual estimative of the macrophyte coverage in these reservoirs was based on the Braun-Blanquet scale (1979), adapted for this paper, following results in percentage and categorized in classes: class 1 (0 – 5%), class 2 (5 – 20%), class 3 (20 – 50%), class 4 (50 – 70%) and class 5 (70 –100%). Hence, the occurrence percentage was classified by the percentage of visual coverage of the *U. arrecta* banks, in relation to the total area of each ecosystem.

For the determination of the species richness, the species were collected, identified and later accommodated in functional groups, characterized by the morphology of each species (Pedralli, 1990).

The sampling in the Vaca-Brava and Rio do Canto reservoirs was performed in eight points, distributed in the *U. arrecta* banks found in both reservoirs, by means of the 1 x 1 m wood square method, establishing a visual and subjective coverage, with the aim to compare the environments. The biomass analysis was made by means of the 0.5 x 0.5 m square method (Westlake, 1974), in the central part of the 1 m² square. After the collection, the individuals were conditioned in plastic bags and transported to the laboratory, where they were weighted and the fresh biomass was obtained.

The average percentage of the intensity of the *U. arrecta* infestation in the environments was obtained by means of the product of the fresh biomass by the product of the percentage of visual coverage. For the analysis, a completely randomized design was performed, with two treatments (Vaca Brava and Rio do Canto reservoirs), and eight repetitions in each treatment, with the goal to determine the relations of the predictor variable (depth) over the other variables. The data were submitted to the analysis of covariance, using the R program (R Development Core Team, 2006). The obtained data were geo-referenced with the ArcGis program (v. 9.3).

RESULTS AND DISCUSSION

U. arrecta populations are highly resistant to drought and to the fluctuations in the reservoir levels, registering high recovery rate in environments where the reduction of their colonization

was observed (Thomaz et al., 2009a,b), high growth and allocation of resources in comparison to other grasses (Bianco et al., 2015), however, this scenario was not compatible with the low infestation rate and structure of populations in the studied basin.

Reservoirs may propagate and passively disperse exotic plants, functioning as "stepping-stones" (Havel et al., 2005). The presence of *Urochloa arrecta*, registered in 37 of the 40 studied reservoirs, indicated broad distribution among the ecosystems in regional scale, whereas the majority of the reservoirs (80%) was identified as small (100 km^2), shallow (≤ 5 m) and with intense human occupation and multiple uses (animal drinking water, supply, irrigation, among others). Out of these 37 reservoirs, 36 were accommodated in class 2 (between 5 and 20%), with low percentage of species occurrence in relation to the total area of the reservoir, and only one (Rio do Canto) was accommodated in class 3, with occurrence percentage between 20 and 50% (Figure 1).

Considered a very competitive species, with elevated biomass, the *U. arrecta* is associated to the reduction of the species diversity and the functional diversity of the native macrophytes (Mormul et al., 2010). However, the cause and effect relation between the natives and exotics is still little discussed. Thus, the reduction of the richness of the native species may accelerate the invasion of exotic species in more vulnerable ecosystems (Fridley et al., 2007), and areas with great availability and heterogeneity of resources and high richness of native species are not excluded in relation to the invasion.

In the results of this study, the direct association between the richness of native species and the dominance of *U. arrecta* was not established, however, the local richness (≤ 10) and

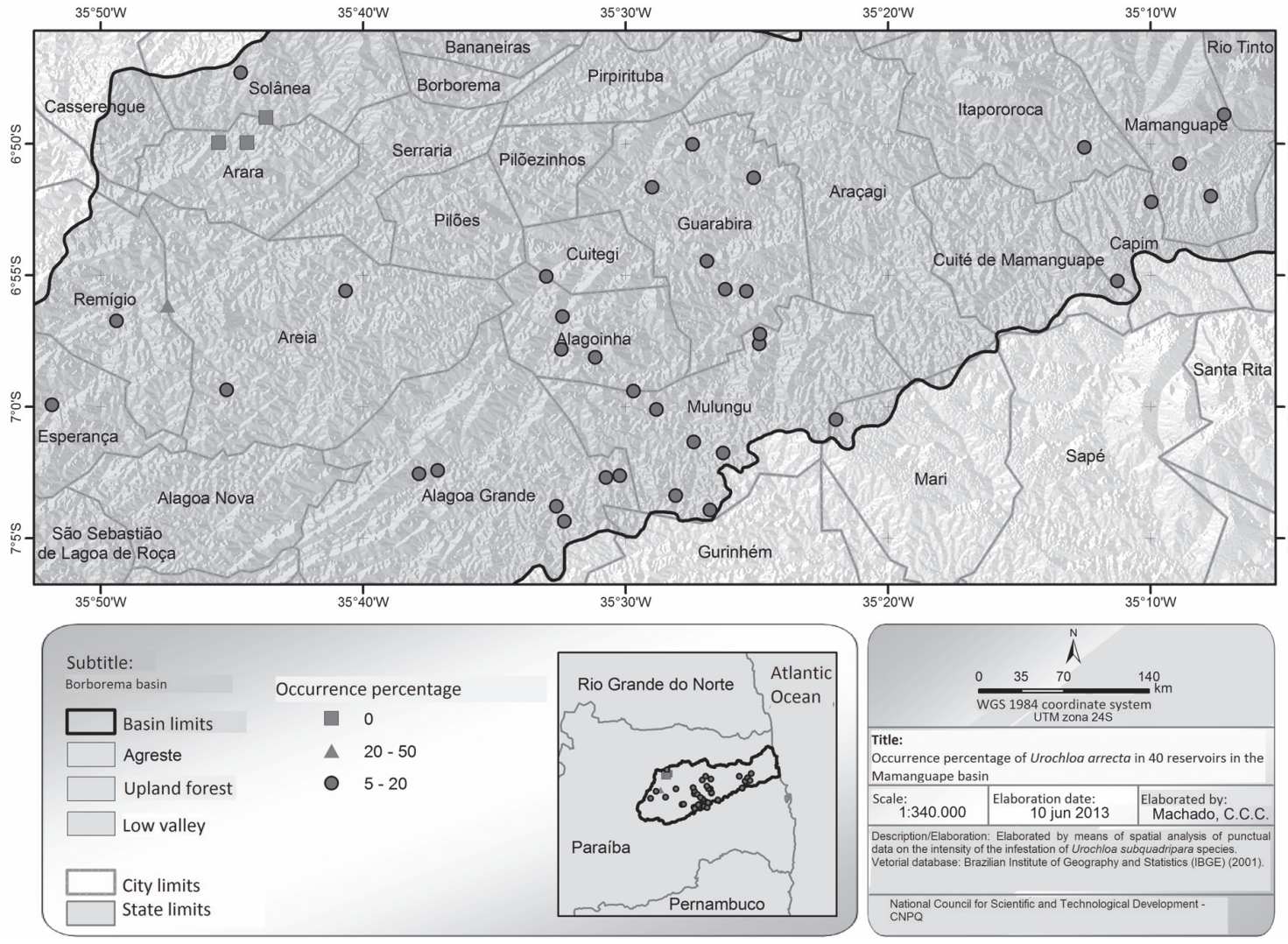

Figure 1 **-** Percentage of the occurrence in 40 environments of the influence area of the Mamanguape river basin.

regional richness (≤ 14) was low, regardless of the size of the reservoir, the rate of *U. arrecta* infestation and the associated abiotic factors. Among the factors associated to low regional and local native richness, the low environmental heterogeneity, the elevated intensity of presented anthropic disturbances (broad human occupation and disposal of affluent, reduction in the coverage of riparian vegetation) as well as natural disturbances of high intensity and frequency (ex: habitat intermittency), may not have favored the generation of environmental gradients with high variability, thus supporting less richness of species. These synergistically influent factors indicate vulnerability of the habitats acting on the natives and exotics, promoting the reduction of the richness of the native and low rate of infestation of the exotics. In this way, the density and richness of native species of macrophytes may interfere in the invasion of the *U. arrecta*, but they cannot prevent the occurrence of the invasion (Michelan et al., 2013).

Despite the indication that the rooted macrophytes are limited to colonize the seaside regions, generally with low depth and declivity (Thomaz et al., 2003), the results indicated absence of a direct relation between the shape of the reservoir and the coverage visual estimative of macrophyte in regional scale, being observed only in the thinner scale, in the Rio do Canto and Vaca Brava reservoirs.

Significant differences in the average percentage of the infestation between the Vaca Brava (63.75%) and Rio do Canto (85%) ($p > 0.05$) reservoirs were not observed. However, the width of the macrophyte banks was larger (7.6 m) in the Rio do Canto reservoir, with significant difference in relation to Vaca Brava (2.56 m) (Table 1), occurring in wider, continuous ranges, and with less biomass – factors associate to its less declivity (35%). On the other hand, in the Vaca Brava reservoir, the higher declivity (45%) (Table 1) did not favor the continuity of the banks, which were punctual and less wide, however with higher fresh biomass (268.75 g), with significant difference in relation to the Rio do Canto reservoir (Figure 2).

Table 1 - Depth of the banks (m), Width (m) and Declivity of the *Urochloa arrecta* banks in the Rio do Canto and Vaca Brava Reservoirs

	Depth of the banks (m)	Width of the banks (m)	Declivity (%)
Rio do Canto	2.06 (±0,27)	7.66 (±5.7)	35 (±0.14)
Vaca Brava	1.11 (±0,31)	2.56 (±0.80)	46 (±0.14)

The inconclusive results indicate that the differences between the colonizable and non colonizable areas within the reservoirs are more important than the differences between the reservoirs. In this sense, the minor depth in the Rio do Canto reservoir favored the colonization of *Urochloa arrecta,* promoting the occurrence of wider and continuous banks, compromising the water mirror and changing the shape of the reservoir from almost circular to a shape similar to a narrow river, when compared to the Vaca Brava reservoir, which is more profound and has higher declivity (Figure 3).

In the Rio do Canto reservoir, in addition to the broad occupation of *U. arrecta*, the occurrence of *Polygonum* sp. (maximum humid weight = 623 g and dry weight = 296 g) indicated elevated vulnerability of the ecosystem to the rooted species with invasive potential, whereas the absence of occurrence overlapping of both species observed in the banks is an indicative of a potential competition.

Factors such as shadowing are important in the reduction of the invasion of exotic aquatic grasses (Thomaz et al., 2012). Despite the elevated biomass obtained in the Rio do Canto and Vaca Brava reservoirs, the shadowed areas registered expressively lower values of *U. arrecta,* as well as of native species, and points with larger riparian vegetation were visualized, where the *U. arrecta* banks were not developed. It suggests that the shadowing arising from the riparian vegetation in the margins is limiting to the development of the species (Thomaz et al., 2012), mainly in Northeastern waters, in which the photoperiod and light availability favor the vegetative propagation and development.

Hence, the initial hypothesis was rejected, and it was concluded that there is a broad spatial distribution of *U. arrecta* in the studied reservoirs, however, with low density and intensity of infestation (below 20%); this indicates that the same factors acting over the low richness of native species represent natural mechanisms to the advance of the infestation of exotics, such as *U. arrecta.*

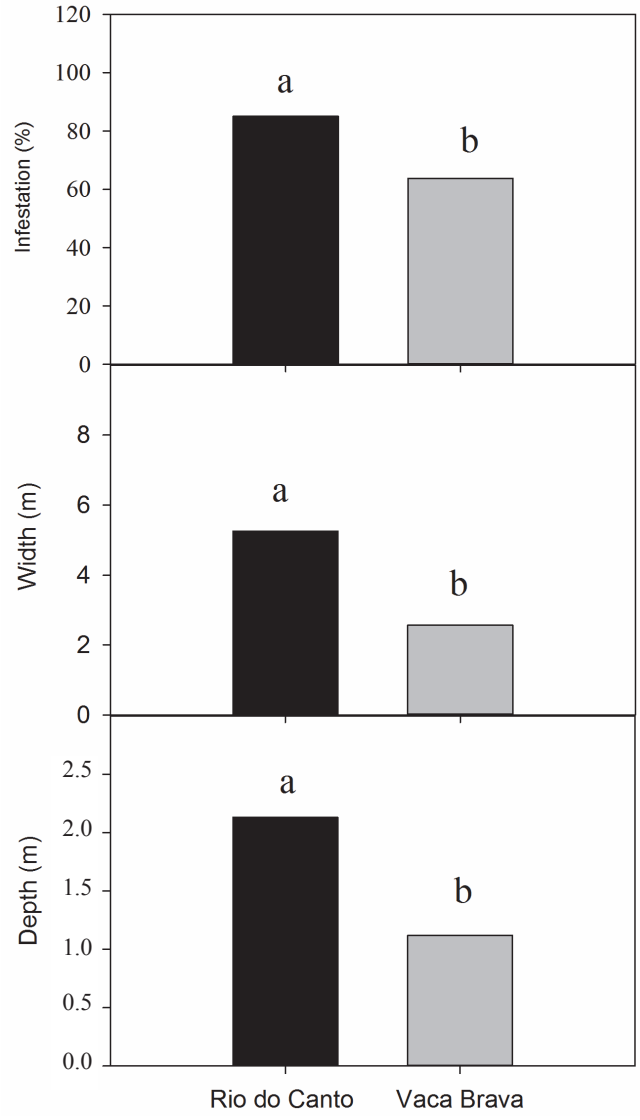

Figure 2 **-** Data on the occupied area and depth of the sampled points in Rio do Canto and Vaca Brava reservoirs.

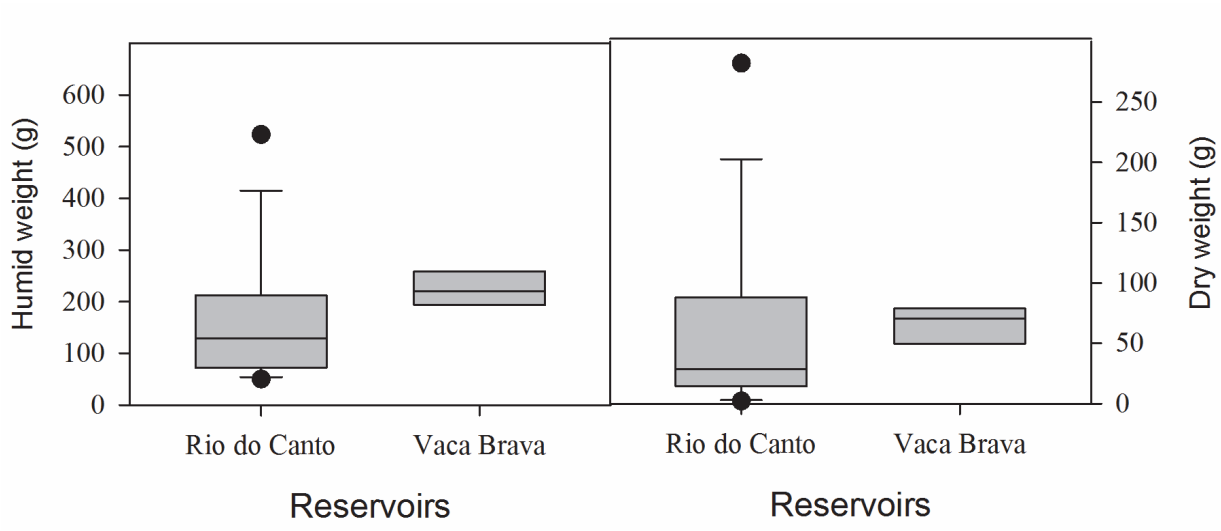

Figure 3 **-** Infestation of *Urochloa arrecta*, confirmed by the production of humid and dry biomass in the Rio do Canto and Vaca Brava reservoirs.

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