Acta Scientiarum

http://www.periodicos.uem.br/ojs/
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v44i1.59212

Socio-environmental assessment of the impact of the African snail, *Lissachatina fulica* (Férussac), 1821, on the population of Alto Paraíso de Goiás, Brazil

Lígia Cristina Cazarin-Oliveira[1], Leonardo Pereira Fraga[1], Manoela Volkweis Lombardi[2], Fabiana Sperb Volkweis[3] and Maria Júlia Martins-Silva[1,2*]

[1]Centro UnB Cerrado, Universidade de Brasília, Avenida Ary Ribeiro Valadão Filho, Área de Expansão Urbana, Gleba 02, 73770-000, Alto Paraíso de Goiás, Goiás, Brazil. [2]Laboratório de Bentos, Departamento de Zoologia, Universidade de Brasília, Brasília, Distrito Federal, Brazil. [3]Universidade Estadual Paulista "Júlio de Mesquita Filho", Jaboticabal, São Paulo, Brazil. *Author for correspondence. E-mail: mjsilva@unb.br

ABSTRACT. The introduction of the African snail *Lissachatina fulica* worldwide poses a risk to the environment, agriculture and human health. Considered a socio-environmental pest it causes problems to plantations and gardens, in addition to threatening native species. Also, it can be an intermediate host of worms that affect humans and mammals. This work aims to evaluate the socioenvironmental impact caused by *L. fulica* in Alto Paraíso de Goiás, Goiás, Brazil. Specifically, it aimed to analyze the residents' knowledge about *L. fulica*, if they were able to recognize the invasive snail and differentiate it from the giant native snail *Megalobulimus* sp., in addition to the community's ability to carry out actions to combat the invasive species. Semi-structured interviews were conducted, guided by a questionnaire, with the urban population, and an unstructured interview with a health surveillance agent in the municipality. The area of the city was divided into five zones and ten residences were visited in each zone. It was found that the residents most affected by *L. fulica* are those who live in the most urbanized region of the city, with 86% of respondents reporting seeing the animal in the city center. The presence of the *Megalobulimus* sp. was reported by four residents in the city's border regions with the native Cerrado. Most of the reports of the African snail in the houses occurred by residents of Alto Paraíso de Goiás who had plants in their backyard and personally took care of them.

Keywords: mollusk; invasive species; African snail; socio-environmental.

Received on May 13, 2021.
Accepted on October 28, 2021.

Introduction

Lissachatina fulica (Férussac, 1821), popularly known as African snail, is a land pulmonary gastropod (Teles, Vaz, Fontes, & Domingos, 1997) with a conic oblong shell of a greyish color with dark brown longitudinal stripes (Simião & Fischer, 2004). Referred to as giant due to its differentiated size, with its shell measuring up to 20cm in length, it has a body mass above 200g (Eston, Menezes, Antunes, Santos, & Santos, 2006). It is an herbivorous animal with generalist and nocturnal habits, becoming more active after sunset. It proliferates easily by depositing approximately 300 eggs at a time as well as being a hermaphrodite with mutual fertilization (Simião & Fischer, 2004; Colley & Fischer, 2009).

Originating in East Africa it was disseminated anthropically in the world for commercial ends. According to Teles et al. (1997), the dissemination started at Hawaii in mid-1939 and today it can be found in the African, American, East and Southern Asia and Oceania continents, especially in temperate regions (Thiengo, Faraco, Salgado, Cowie, & Fernandez, 2007). Currently, the giant African snail belongs to the list of the 100 worst invasive alien species of the world, representing an environmental pest and causing problems to the environment, agriculture, and the human and animal health (Eston et al., 2006; Thiengo et al., 2007; Sobrepeña & Demayo, 2014). Competition for resources between native and invasive alien species also is disadvantageous, as invasive species are generalist and easier to survive in overlapping niches (Simião & Fischer, 2004; Eston et al., 2006; Gregoric, 2011). Exotic species of mollusks are better adapted to anthropized environments, presenting a higher rate of recolonization and leading native species to lethargy and death (Eston et al., 2006).

In places where the infestation has not been controlled, it has become an agricultural pest, as it attacks various crops, in particular, vegetables, and coffee (Simião & Fischer, 2004). *Lissachatina fulica* has been found

to be an intermediate host of 20 species of worms that have several mammals as their definitive hosts: rodents, cattle, horses, sheep, primates, dogs, and cats (Madella & Auricchio, 2014). The giant African snail can also transmit two dangerous worms for human being: *Angiostrongylus cantonensis* (Chen, 1935) that causes eosinophilic meningitis and *Angiostrongylus costaricensis* (Morera & Céspedes, 1971) causer of the abdominal angiostrongyliasis (Teles et al., 1997; Thiengo et al., 2010; Madella & Auricchio, 2014; Almeida, 2016).

Several methods of controlling the populations of *L. fulica* have been studied and tested, such as chemicals and biological control (Madella & Auricchio, 2014; Silva & Machado, 2017; Santos, Negrisoli, Santos, & Negrisoli Junior, 2018). Synthetic products have been used as a combat process, but the knowledge about substances such as molluscicides is still small and its use can end up polluting the soil and killing native species (Zanol, Fernandez, Oliveira, Russo, & Thiengo, 2010). The biological control has been tested on islands in the Pacific and Indian Oceans and has proved inefficient, as the case of predator mollusk *Euglandina rosea* (Férussac, 1821), which wiped out native species and failed to control the population of *L fulica* (Thiengo et al., 2007). So far, the most efficient combat has been manual collection and sanitation measures, which do not pollute the soil and are effective in combating the invasive snail, without affecting native species (Colley & Fischer, 2011; Almeida, 2016; Santos et al., 2018).

It was brought to Brazil in three different moments, two of which, according to Thiengo et al. (2007) with commercial objectives as a cheaper substitute for the *escargot*. These moments were: in 1989 in the State of Paraná, and between 1996 and 1998 in the State of São Paulo. Also, and without much information, in 1972 or 1975 in the State of Minas Gerais (Zanol et al., 2010). It is currently found in 23 of the 26 states and in the Federal District. The species adapts easily to modified environments ranging from abandoned plots to huge trash deposits, as the vegetation and accumulated material serve as shelter and protection for egg laying (Thiengo et al., 2007; Silva, Santos, Melo & Jeraldo, 2019; Chatap Pravin, Deshmukh & Telkhede, 2020. The arboreal habit allows him to climb trees and walls (Silva, Santos, Melo, & Jeraldo, 2019; Cazarin-Oliveira, Fraga & Martins-Silva, 2021). The gregarious behavior invites population explosions harassing neighbors as it attacks mainly ornamental and vegetable gardens. There is, therefore, intense demand for authorities to find a solution for the problem by people affected by the snails (Thiengo et al., 2007; Zanol et al., 2010; Colley & Fischer, 2011).

Lissachatina fulica also causes environmental concerns as it adapts easily to varying environments, colonizing not only cities but forest areas, forest fringes and recovering forests (Thiengo et al., 2007). It is a threat to native snails, especially of *Megabulimus* sp. Which by being larger than average are confused with the invading snail and killed, either by the use of mollusk pesticides or wrong collection during combat campaigns (Fischer & Coelly, 2004). The competition for resources with the exotic and invasive species is unfavorable as the invading species is generalist and has greater chances of surviving in cracks and corners, besides adapting better to anthropic environments, having a higher colonization rate and bringing the native species to lethargy and death days after contact (Eston et al., 2006). According to Fontenelle and Miranda (2017), the *Megabulimus* spp are part of a group of giant neo-tropical terrestrial snails known as Aruá-do-mato, with 63 different species in Brazil. They have nocturnal habits, spending days in dormancy; long life; low population density with small reproductive potential, with a maximum of five eggs per copulation, per individual (Fontenelle & Miranda 2017).

The current work aimed at evaluating the socio-environmental impact of the giant African snail, *L. fulica*, for the inhabitants of Alto Paraíso de Goiás, verifying the information the municipal population has on the risks and problems caused by the exotic invasive species and checking if they can recognize it and see the difference from the native giant snail, *Megabulimus* spp. Additionally, assess their knowledge of correct combat and handling of the species so that a plan of action for environmental education and combat of the invasive mollusk, while preserving the native snails, may be traced.

Material and methods

The study was undertaken in the municipality of Alto Paraíso de Goiás (14º8'1" S and 47º31'17" W), northeastern of Goiás State. The climate in the region is Köppen's Aw (rainy tropical), with a marked seasonality between the dry and rainy seasons (Alvares et al., 2013; Cardoso, Marcuzzo, & Barros, 2015). Data collection took place from July 23 to 27, 2018 (the dry season in the region). The Brazilian savanna (Cerrado biome), located in central Brazil, is the largest open vegetation domain in South America (Klink & Machado, 2005; Werneck, 2011). Much of the municipality of Alto Paraíso de Goiás is located in the buffer zone of the

Chapada dos Veadeiros National Park. The National Park is an emblematic protected area of the Cerrado, being considered by UNESCO as a Natural Heritage of Humanity.

Alto Paraíso de Goiás has an area of 2,593,905 km² and a demographic density of 2.65 cit/km². Only 45.8% of the residences have sewers and sanitary installations; 91.9% of the public streets are tree lined and 4.4% are urbanized (IBGE, 2017). The main economic activities of the region are ecotourism and agriculture. The city has a large number of small inns and houses for season renting, with large yards and some type of vegetation. There is an important mystical culture and vocation for anthropic activities such as agricultural expansion, mineral mining, native plant extraction, hunting and uncontrolled tourism besides the introduction of exotic species.

The city of Alto Paraíso de Goiás corresponds to 28% of the Environmental Protection Area - APA of Pouso Alto and it is the entrance to the National Chapada dos Veadeiros Park, considered a Natural World Patrimony by UNESCO. The region is part of the Cerrado Biome, characterized by a savanna-like tropical vegetation, with approximately 120 waterfalls and several water springs. With 6,885 inhabitants, the destination of trash receives no adequate treatment and is thrown into an area of approximately 8 acres, open air and close to the Couros River, to water springs and the park muffling zone (IBGE, 2017).

For the interview, the urbanized area of the municipality of Alto Paraíso de Goiás was divided into five zones (Figure 1): North, South, East, West and Center. The North zone was composed by: Centro, Loteamento Residencial Eldorado and Vila Bandeira neighborhoods; South, with the neighborhoods of Novo Horizonte and Monte Sinai; East with Estância Paraíso, Paraíso Velho and Vale Azul neighborhoods; West, with Bairro Alta and Planalto sectors were included; and the central area comprised the Paraisinho neighborhood. In each zone, ten houses were visited, chosen randomly and with distance between them. In the houses, the researchers introduced themselves, informed the reason for the research and asked the interviewees to sign the Free Consent Form to carry out the research, informing them that the interviews would be recorded.

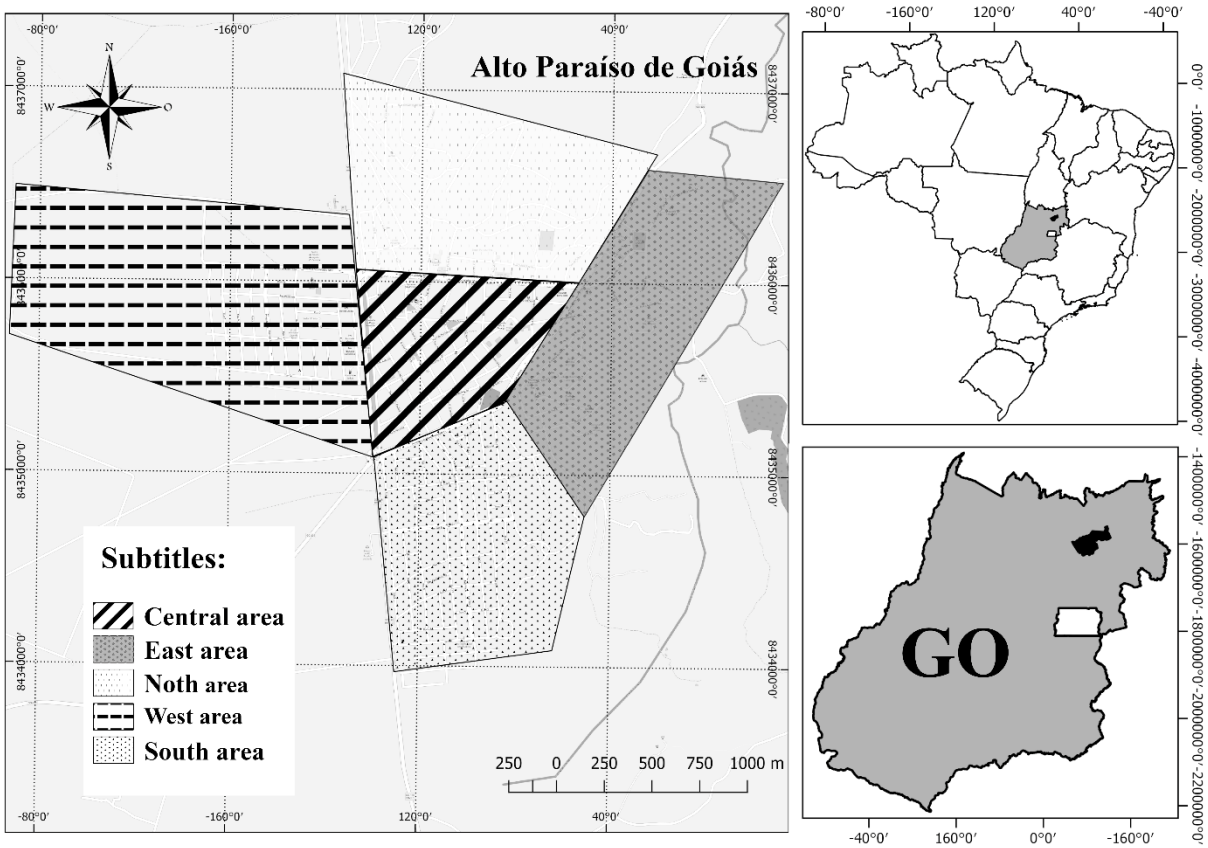

Figure 1. Divisions of the Alto Paraíso de Goiás urban area for the study. Urbanized area division: North (Loteamento Residencial Eldorado and Vila Bandeira), South (Novo Horizonte and Monte Sinai), East (Estância Paraíso, Paraíso Velho and Vale Azul), West (Bairro Alta and Planalto sectors) and Central (Paraisinho).

In each house, the interview started with the presentation of two images and two shells, one of *L. fulica,* and the other of *Megalobulimus* sp., belonging to the collection of the Bentos Laboratory of *Universidade de*

Brasília (UnB). Respondents were asked the following questions: a) sex, age and time of residence in Alto Paraíso de Goiás; b) if they had a backyard, vegetable garden or ornamental plants at home; c) the giant African snail *L fulica* was known; d) if *L. fulica* had been found in his home or elsewhere in the city; e) the native giant snail *Megalobulimus* sp. was known; f) if *Megalobulimus* sp. had been found in his home or elsewhere in the city; g) ways of collecting and combating *L fulica* were known; h) what were the main difficulties they come across to combat *L. fulica*. In addition, an interview (recorded and unstructured) was carried out with a sanitary agent (responsible for health monitoring in Alto Paraíso de Goiás), in order to verify if the municipal authorities were aware of the presence of *L. fulica*, if there was any campaign to combat the invading snail, and if there was any record of patients diagnosed with eosinophilic meningitis or strongyloidiasis, in the municipality.

The geographical coordinates of the houses visited were marked with GPS (Garmin Etrex 30). The points were used to differentiate: a) places where the interviewees reported having found the giant African snail; b) places where the interviewees reported *Megalobulimus* sp; c) places where none of the snails have ever appeared. There was also a superficial search for individuals of the species in the houses visited. The collected mollusks (live individuals and empty shells) were counted, marked and packed in 70% ethanol. The samples were taken to the Bentos Laboratory in Brasília, for the disposal of the UnB Mollusk Collection.

Research was based on semi-structured taped interviews, using a questionnaire as a non-nominal. The audios were transcribed and analyzed, with yes and no answers quantified and a statistical EXCEL calculation performed. A qualitative analysis with EXCEL and generating graphs was also undertaken, in which the questions of the questionnaire that allowed for un-patterned answers were standardized with synonyms.

Results

Twenty samples of the invading species were found in 7 different places from July 23 to 27, 2018, during the dry period of the region. The search took place in a superficial manner, based on the indication of a resident who had sighted one recently. In most places only one individual was found or an empty shell. In one residence, however, two live dormant samples were collected, and 13 shells were found in another residence in traps set by the owner. All collection sites had plants and the sample collected in the street was in a place surrounded by trees.

Of the 50 residents interviewed 52% were female and 48% were male. Their age ranged from 14 to 80 years, being 40% of them 26 to 35 years old. In their yards 60% of the residents had some sort of vegetation, varying from ornamental pants, to fruit trees and vegetable gardens.

About 80% of respondents have heard about the *L. fulica*. Most problems associated with the specie were related to disease transmission (30%) followed by losses in vegetable gardens (18%). Even with the reported problems, only eighteen interviewees (36%) have already taken effective measures to combat the invading snail. Four respondents (8%) said that they caught *L. fulica* with their hands without any kind of protection. Only eight interviewed (16%) knew the recommended ways to combat the *L. fulica* (such as crushing both the shell and the eggs and burying them in holes sealed with lime). Some of the interviewees mentioned difficulties in fighting against, by the fact that they did not find molluscicides in local commerce, that not all neighbors were involved in the combat, and that the City Hall was not encouraging the collection of the invading snail.

Among those interviewed, 46% stated having found a giant snail in their homes, and 19 (38%) of these said the snail found was that of the photo and shell of the *L. fulica*, while four (4%) associated the photo and the shell of the *Megalobulimus sp*. with those they had found. In the houses and backyards visited, twenty samples of *L. fulica* were found, at seven different points. In most collection points, only one empty shell was found. But, in one residence several snails were collected, in trap made by the resident himself. Two individuals dormant were found in another house. In all the collection sites, there were plants in the backyards.

The analysis of the GPS markers revealed that that the main area of *L. fulica* occurrence was the central more urbanized area of the city (Figure 2). Seventeen of the twenty samples were collected in that region. The occurrence of *Megalobulimus* sp. was reported in regions bordering the city with the native cerrado (Figure 2). However, 86% of those interviewed claimed to also have seen the invading snail in the city, more specifically in the Paraisinho and Novo Horizonte neighborhoods. A distinguishing factor among residents who had found specimens in their yards was their having plants in the area (Figure 3), take care of the garden and live in Alto Paraíso de Goiás for more than a year.

The reactions to the snails went from discomfort, fear, disgust, throwing far away or in the trash, killing, indifference and sympathy with the mollusk. Among those who reported finding the exotic snail, 54%

mentioned inconvenience. Despite the problems that were reported, only 18 of those interviewed took any kind of action to eliminate the invading species. Some considered the combat a responsibility of the community health staff while others explained they did not have the courage to kill the animals.

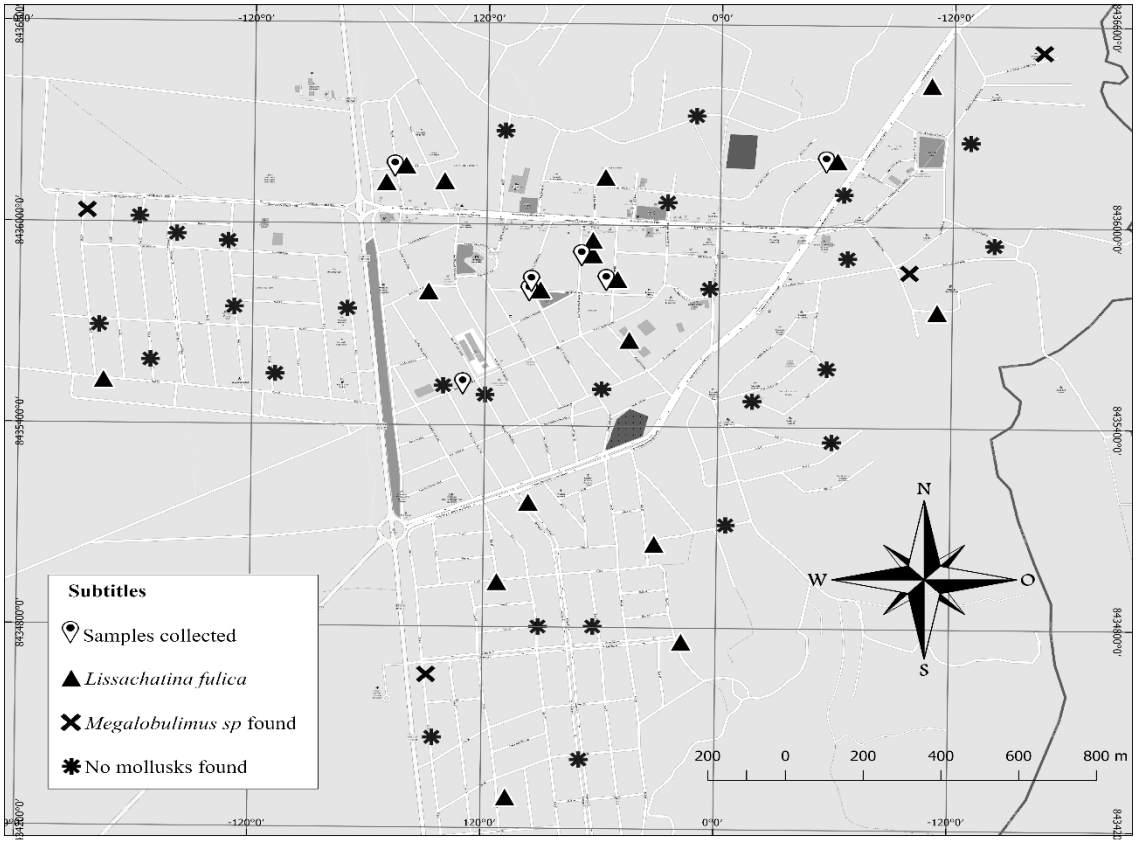

Figure 2. GPS points marked during the survey. Locations of collections and interviewed residents, differentiating the places where residents reported finding the Giant African Snail, reported *Megalobulimus* sp., and those who reported that none of the snails had ever appeared.

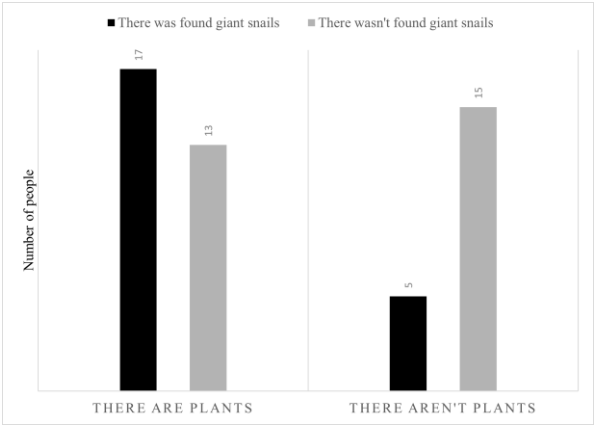

Figure 3. Respondents who found giant snails. Among the interviewees, 28 never saw any giant snails in their property, 22 said they had found a large snail, 19 pointed that the snail found was *Lissachatina fulica*, while 4 indicated it was *Megalobulimus* sp. The graph distinguishes whether in the interviewees' property there were plants in their backyard. Among those who had plants, 17 individuals found the giant snail in their residence (only the shell or alive) and 13 did not. Of those who had no plants, only 5 found it, while 15 found no giant snails in their property.

The most common act amongst those interviewed was throwing the snail in the trash (six reports), sometimes alive and sometimes killed with some substance such as salt (seven people reported doing this), lime (four people used the substance), and mollusk poison – a nonspecific poison against gastropod mollusks (two people). Some people mentioned as a difficulty in combating the snail the lack of poison in the region, the fact that not all neighbors got involved in combating the snail and the community health staff was no

longer collecting the animals. The handling of the snails, as informed in most interviews, was by indirect means, with either spade, a mason spoon, cardboard or wood; some with gloves or trash bags but there were still a few who handled the animals with their hands.

Approximately 80% of those interviewed had heard something about the giant African snails and, based on 31 accounts most information is related to disease transmission. Furthermore, 4 individuals named the diseases they thought to be transmitted by the snail: meningitis, ascites and esquistossomosis. Thirteen people said one may not touch them, and another thirteen said it is poisonous. Eight residents knew the correct way to dispose of the snail, crushing both shell and eggs and burying them in lime waterproofed holes. Only fifteen of the people interviewed had heard about how the snail arrived in town, with accounts of it having been brought from somewhere, that the idea was to sell them as food and that the breeding ground was close to the hospital. This information was repeated by the sanitary agent but there is no official record at the City Hall, and there was one person who said the person who brought them died from breeding the mollusk.

As far as the diseases transmitted by the invading species, one resident said there had been an outbreak of the intestinal disease the snail transmitted and that she herself had felt the symptoms, another person said her aunt had been diagnosed with a disease connected to the giant African snail but neither knew the name of the disease nor had medical documents to attest this. At the Municipal Health Office no record of patients diagnosed with diseases related to the snail were found.

The representative of the Health Office informed, during the interview, that City Hall was aware of the presence of the *L. fulica* in the municipality, and that complaints had been made about the infestation and an attitude demanded. From 2008 to 2010 City Hall responded by handing out brochures published by the State of Goiás on the invading species, the correct way to handle it, and how to fight the infestation. There was also joint effort among municipal agents and workers with the population to clean the streets and yards and collect the animals. In this campaign against the snails, authorities had difficulties due to a lack of population support who would not allow the cleaning of their yards, which, according to the sanitary agent, contributed to the re-colonization of the environment.

The collection of the snails was interrupted for lack of agents to collect the animals and because the population was taking live snails in trash bags and leaving them in front of the hospital. According to the health agent, 800 kilos were collected in two months. A further issue is the lack of official population complaints to the health authorities, and on actions taken within the properties as people do not file formal complaints and have the tradition of asking for help informally.

Still according to the interviewee, regarding the diseases transmitted by *L. fulica* the tests carried out previously had a negative result regarding the contamination of mollusks by the helminths that cause eosinophilic meningitis or abdominal angiostrongyliasis. Therefore, the campaigns developed by the municipal government are only educational, and, for now, there is no way to make the participation of the population mandatory.

Discussion

Lissachatina fulica has been a problem for the residents of Alto Paraíso de Goiás for at least a decade, according to the Health Office of the city. The most affected residents are those who live in the central area, in the neighborhoods of Paraisinho, Centro and Novo Horizonte, who have some sort of garden for which they care directly. The preference of the mollusks for this home profile is due to an even better adaption to urban environments, humid and with available food and protection (Almeida, 2016; Santos et al., 2018). Silva et al. (2019) observed similar results in research conducted in the city of Aracaju, state of Sergipe, Brazil. In that study, the researchers observed a more representative occurrence of *L fulica* in urban areas, mainly in vacant lots (Silva et al., 2019).

The empty shells and the small number of dormant snails (n = 2) correspond to the results obtained by Simião and Fischer (2004) in studies carried out during the winter in urban environments. In our study, the small number of samples of *L. fulica* can be justified by the research carried out during the dry season. Silva and collaborators (2019) observed a correlation between rainfall and the frequency of the invasive snail.

With the problems reported by residents, ranging from predation of plants in their gardens and vegetable gardens, to the large number of individuals present in the rainy season, bringing bad smell and visual discomfort both for those who live in the region and for tourists. In addition, the population expresses fear of diseases that can be transmitted by snails. Thiengo et al. (2010), in the State of São Paulo, have already found

larvae of *Angiostrongylus cantonensis* in *L. fulica*, cases of eosinophilic meningitis reported in the states of Espírito Santo and Pernambuco and *Angiostrongylus costaricencis* present in several Brazilian states. Urgent action against the giant African snail is considered necessary not only for the comfort of residents, but also to prevent human, animal and environmental health problems, not to mention agriculture.

Some residents alerted to the presence of the native species, found at the margins of the city and, according to some, close to rivers. This is due to the fact that this mollusk does not adapt well to the urban environment, where it has yet to be seen. However, one of the concerns about the invading gastropod is the fact that the species may be a threat to the *Megalobulimus*, particularly as it lays much less eggs than the invading snail. *Megalobulimus* snails have the behavior of failing into lethargy, till death, in the presence of the African snail (Eston et al., 2006). A further threat is the use of snail poison, mechanic methods and biological control forms that may affect native species and sometimes do not solve the problem of the African snails effectively (Thiengo et al., 2007; Zanol et al., 2010).

Another environmental factor to be taken into consideration when discussing the *L. fulica* infestation is the impact on the Environment Protection Area – EPA of Pouso Alto. According to Eston et al. (2006), the voracity of this species and its easy population increase may diminish availability of food for the native fauna of the region, altering the natural landscape due to the consumption of biomass such as plant buds, young plants and plant meristem. Awareness of this risk increased as residents reported throwing live snails in the trash. City trash is all piled together, within the environmental protection area and, with food, shelter, no predators, the dispersion of these animals, possibly reaching the native Cerrado vegetation is indeed a serious risk.

The main socio-environmental impacts resultant from the presence of the giant African snail *L. fulica*, according to the residents of Alto Paraíso de Goiás, are represented by losses in vegetable gardens and a threat to the native snail populations. There were no direct risks of diseases caused by *L. fulica*, since there are no records of these diseases in the municipality. However, we believe it is important to control the invasive snail population because, according to Teles et al. (1997), the Federal District (just 160 km away) is a region of incidence of the worm *Angiostrongylus costaricensis*. For this control, an environmental education campaign involving lectures for residents who have agricultural or gardening practices in their plots, with students and teachers in municipal schools is advisable. It is also feasible to use a well-illustrated booklet as support material, with resources that are easier and more accessible to read and understand by everyone, whether residents or regulars in the region. It must explain the correct mechanisms to fight against the invader, explaining the risk of use of molluscicides and other non-combat specific poisons, as they do not just kill the African species.

Conclusion

This work evaluated the socioenvironmental impact caused by *L. fulica* infestation in Alto Paraíso de Goiás. Our analyzes revealed that the main area of invasive snail occurrence was the central area of the city.

Few interviewees took any kind of action to eliminate the invading specie.

Environmental education campaigns are required with residents who have agricultural or gardening practices on their plots, as well students and teachers in city schools should.

The report of residents about the presence of native snail *Megalobulimus* sp. in the regions bordering city highlights the need for urgent environmental education work.

Acknowledgements

We thank the directors and employees of the UnB Cerrado Center that provided or requested interviews and collections, a civil community in Alto Paraíso de Goiás that took part in the research, and the Health Surveillance Agent, who assisted with the necessary health information.

References

Almeida, M. N. (2016). Caramujo africano: apenas uma espécie introduzida ou um problema de saúde pública? *Acta Biomedica Brasiliensia, 7*(2), 76-86. DOI: https://doi.org/10.18571/acbm.112

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Moraes, G., Leonardo, J., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711-728. DOI: https://doi.org/10.1127/0941-2948/2013/0507

Cardoso, M. R. D., Marcuzzo, F. F. N., & Barros, J. R. (2015). Classificação climática de Köppen-Geiger para o estado de Goiás e o Distrito Federal. *Acta Geográfica, 8*(16), 40-55. DOI: https://doi.org/10.5654/acta.v8i16.1384

Cazarin-Oliveira, L. C., Fraga, L. P., & Martins-Silva, M. J. (2021). Primeiro registro de *Achatina fulica* Bowdich, 1822 na Vila de São Jorge, estado de Goiás, Brasil. *Revista Agaronia*, *3*(2), 24-27.

Chatap Pravin, B., Deshmukh, U. B., & Telkhede, P. M. (2020). An invasion of *Achatina fulica* Bowdich in Chandrapur District (Vidarbha Region), Maharashtra (India). *The International Research Journal of Science and Engineering, Special Issue* (A7), 417-421.

Colley, E., & Fischer, M. L. (2009). Avaliação dos problemas enfrentados no manejo do caramujo gigante africano *Achatina fulica* (Gastropoda: Pulmonata) no Brasil. *Zoologia*, *26*(4), 674-683.

Colley, E., & Fischer, M. L. (2011). O caramujo gigante africano *Achatina fulica* no Brasil. *Estudos de Biologia*, *32*(76/81), 123-126. DOI: https://doi.org/10.7213/reb.v32i76/81.22880

Eston, M. R. D., Menezes, G. V., Antunes, A. Z., Santos, A. S. R. D., & Santos, A. M. R. D. (2006). Espécie invasora em unidade de conservação: *Achatina fulica* (Bowdich, 1822) no Parque Estadual Carlos Botelho, Sete Barras, SP, Brasil. *Revista do Instituto Florestal*, *18*(1), 173-179.

Fischer, M. L., & Colley, E. (2004). Diagnóstico da ocorrência do caramujo gigante africano *Achatina fulica* Bowdich, 1822 na Apa de Guaraqueçaba, Paraná, Brasil. *Estudos de Biologia*, *26*(54), 43-50.

Fontenelle, J. H. & Miranda, M. S. (2017). Aspects of biology of *Megalobulimus paranaguensis* (Gastropoda, Acavoidea) in the coastal plain of the Brazilian southeast. *Iheringia. Série Zoologia, 107*(1), 1-5. DOI: https://doi.org/10.1590/1678-4766e2017004

Gregoric, D. E. G., Núñez, V., Vogler, R., & Rumi, A. (2011). Invasion of the Argentinean Paranense rainforest by the giant African snail *Achatina fulica*. *American Malacological Bulletin*, *29*(1/2), 135-137. DOI: https://doi.org/10.4003/006.029.0205

Instituto Brasileiro de Geografia e Estatística [IBGE]. (2017). *Senso Agropecuário, Florestal e Aquícola*. Retrieved on March 31, 2022 from https://censos.ibge.gov.br/agro/2017/

Klink, C. A., & Machado, R. B. (2005). A conservação do Cerrado brasileiro. *Megadiversidade*, *1*(1), 147-155.

Madella, C. R., & Auricchio, P. (2014). Registro de *Achatina fulica* Bowdich (Mollusca, Gastropoda) no ecótono Cerrado-Caatinga, no sul do Estado do Piauí, Brasil. *Acta Biológica Paranaense*, *43*(1-2), 53-60.

Santos, L., Negrisoli, C. B., Santos, M. B., & Negrisoli Junior, A. (2018). Management of *Achatina fulica* (Bowdich, 1822) (Pulmonata: Achatinidae) in lettuce (*Lactuca sativa* L.). *Arquivos do Instituto Biológico*, *85*(1), 1-15. DOI: https://doi.org/10.1590/1808-1657000262017

Silva, J. D., & Machado, G. E. M. (2017). *Achatina fulica* (Bowdich, 1882) (Gastropoda-Stylommatophora-Achatinidae) - medidas adotadas no controle da espécie em países da américa do sul. *Semioses*, *11*(2), 1-7. DOI: https://doi.org/10.15202/1981996X.2017v11n2p1

Silva, G. M., Santos, M. B., Melo, C. M., & Jeraldo, V. L. (2019). *Achatina fulica* (Gastropoda: Pulmonata): Occurrence, environmental aspects and presence of nematodes in Sergipe, Brazil. *Brazilian Journal of Biology*, *80* (2), 245-254. DOI: https://doi.org/10.1590/1519-6984.190291

Simião, M. S., & Fischer, M. L. (2004). Estimativa e inferências do método de controle do molusco exótico *Achatina fulica* Bowdich 1822 (Stylommatophora; Achatinidae) em Pontal do Paraná, litoral do Estado do Paraná. *Cadernos de Biodiversidade*, *4*(2), 74-83.

Sobrepeña, J. M. M., & Demayo, C. G. (2014). Banding pattern and shape morphology variations on shells of the invasive giant African land snail *Achatina fulica* (Bowdich 1822) from the Philippines. *Annals of Biological Research*, *5*(1), 64-79.

Teles, H. M. S., Vaz, J. F., Fontes, L. R., & Domingos, M. D. F. (1997). Registro de *Achatina fulica* Bowdich, 1822 (Mollusca, Gastropoda) no Brasil: caramujo hospedeiro intermediário da angiostrongilíase. *Revista de Saúde Pública*, *31*(3), 310-312.

Thiengo, S. C., Faraco, F. A., Salgado, N. C., Cowie, R. H., & Fernandez, M. A. (2007). Rapid spread of an invasive snail in South America: the giant African snail, *Achatina fulica*, in Brasil. *Biological Invasions*, *9*(6), 693-702. DOI: https://doi.org/10.1007/s10530-006-9069-6

Thiengo, S. C., Maldonado, A., Mota, E. M., Torres, E. J. L., Caldeira, R., Carvalho, O. D. S., ... Lanfredi, R. M. (2010). The giant African snail *Achatina fulica* as natural intermediate host of *Angiostrongylus cantonensis*

in Pernambuco, northeast Brazil. *Acta Tropica*, *115*(3), 194-199. DOI: https://doi.org/10.1016/j.actatropica.2010.01.005

Werneck, F. P. (2011). The diversification of eastern South American open vegetation biomes: historical biogeography and perspectives. *Quaternary Science Reviews*, *30*(13-14), 1630-1648. DOI: https://doi.org/10.1016/j.quascirev.2011.03.009

Zanol, J., Fernandez, M. A., Oliveira, A. P. M. D., Russo, C. A. D. M., & Thiengo, S. C. (2010). O caramujo exótico invasor *Achatina fulica* (Stylommatophora, Mollusca) no Estado do Rio de Janeiro (Brasil): situação atual. *Biota Neotropica, 10*(3), 447-451. DOI: https://doi.org/10.1590/S1676-06032010000300038