The invasive snail *Lissachatina fulica* (Mollusca: Achatinidae): its population structure in an area of recent colonization in Argentina

El caracol invasor *Lissachatina fulica* (Mollusca: Achatinidae): su estructura poblacional en una zona de reciente colonización en Argentina

Romina Valente[1,3]*, Julia Inés Diaz[1,3], Oscar Daniel Salomón[2,3] & Graciela Teresa Navone[1,3]

[1]Centro de Estudios Parasitológicos y de Vectores (CEPAVE), CONICET, FCNyM, UNLP, calle 120 e/61 y 62, B1900FWA La Plata, Buenos Aires Province, Argentina.
[2]Instituto Nacional de Medicina Tropical (INMeT), Jujuy s/n, 3370. Puerto Iguazú, Misiones Province, Argentina.
[3]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina.
*Autor corresponsal, e-mail: romina_valente81@hotmail.com

Abstract

The giant African snail *Lissachatina fulica* is an invasive mollusk native to Africa. The first record of this snail in Argentina was in Puerto Iguazú, in 2010. *Lissachatina fulica* cause severe impacts as displaces native fauna and produce considerable damage to agricultural systems. For this reasons, it is recognized as one of the world's most damaging pests listed in the Global Invasive Species Database. The objective of this work was to know the population structure of *L. fulica* in function of time and environmental variables in order to analyze and evaluate the establishment of the giant African snail population in Puerto Iguazú, Argentina, an area of recent colonization. The snail shells were measured and separated into four equal size ranges. The results showed that the smaller size (0-3cm) is more represented in the dry season and the intermediate sizes (3-6 and 6-9 cm) in the wet season. The body growth and biomass in *L. fulica* is influenced by environmental factors. This result indicates that *L. fulica* populations are already established in Puerto Iguazú, showing the importance of incorporate management programs and control strategies of this pest.

Key words: exotic species, pest, colonization, human health, control strategies.

Resumen

El caracol gigante africano *Lissachatina fulica* es un molusco invasor nativo de África. El primer registro de esta especie en Argentina fue en Puerto Iguazú, el año 2010. *Lissachatina fulica* causa severos impactos, ya que desplaza a la fauna nativa y produce daños considerables a los sistemas agrícolas. Por esta razón, es reconocida como una de las plagas más dañinas del mundo, enumeradas en la Base de datos mundial de especies invasoras. El objetivo de este trabajo fue conocer la estructura poblacional de *L. fulica* en función del tiempo y variables ambientales con el fin de analizar y evaluar el establecimiento de la población de caracoles gigantes africanos en Puerto Iguazú, Argentina, zona de reciente colonización. Las conchas de los caracoles se midieron y separaron en cuatro rangos de igual tamaño. Los resultados mostraron que la talla más pequeña (0-3 cm) está más representada en la estación seca y las tallas intermedias (3-6 y 6-9 cm) en la estación húmeda. El crecimiento corporal y la biomasa de *L. fulica* están influenciados por factores ambientales. Este resultado indica que las poblaciones de *L. fulica* ya están establecidas en Puerto Iguazú, mostrando la importancia de incorporar programas de manejo y estrategias de control de esta plaga.

Palabras clave: especies exóticas, plagas, colonización, salud humana, estrategias de control.

Introduction

The giant African snail *Lissachatina fulica* (Férrusac, 1821), gastropod belonging to the family Achatinidae Swainson, 1840, is an invasive land pulmonate mollusk native to northeast Africa. The dispersion of the species started at the beginning of the nineteen century in Africa (Raut & Barker, 2002). In 1847, this species was reported for the first time in Asia and then it expanded to almost the entire continent (Cross, 2007).

Lissachatina fulica was observed for the first time in the American continent in 1966, but it was officially reported in 1984, later it was established in several islands in the Caribbean Sea (Alicata, 1991; Cross, 2007). The invasion of South America by this mollusk was in the 90's arriving to Venezuela, Ecuador, Colombia, Brazil, Bolivia and Paraguay (Thiengo *et al*., 2007). The first record of the species in Argentina was in 2010 in Puerto Iguazú, Misiones Province (Gutiérrez Gregoric *et al*., 2011; Diaz *et al*., 2013) and some years later the species was reported in Corrientes Province (Gutiérrez Gregoric *et al*., 2013).

The giant African snail is recognized as one of the world's most damaging pests listed in the Global Invasive Species Database (Lowe *et al*., 2004). This gastropod consumes basically vegetation and, although it is more frequently observed in warm and semi-arid zones, it prefers sites not directly exposed to sunlight, with both high humidity (70%) and temperatures (20°C) (Matinella *et al*., 2009).

The dispersion of *L. fulica* in new areas is mainly due to the anthropocentric influence, because the species is used as exotic food, as exotic pets, as bait to fishing, and is associated with some African religion traditions (Thiengo *et al*., 2007; Neto *et al*., 2012).

This invasive exotic species can establish in new tropical and subtropical areas causing severe impacts as displaces native fauna by habitat and food competition (Beltramino *et al*., 2015) and produce considerable damage to agricultural systems causing economic losses (Matinella *et al*., 2009). However, the main interest in *L. fulica* is its implication in the human health because this mollusk can act as intermediate host of parasites of medical and veterinary importance (Acha & Szyfres, 2003; Thiengo *et al*., 2007). In this sense, this snail harbors the larvae stage of the Metastrongylidae nematodes *Angiostrongylus cantonensis* Chen, 1935, *Angiostrongylus costaricensis* Morera and Céspedes, 1971, *Angiostrongylus vasorum* Baillet, 1866, and *Aelurostrongylus abstrusus* Railliet, 1898 (Ash, 1970; Franco-Acuña *et al*., 2009; Maldonado Jr. *et al*., 2010; Oliveira *et al*., 2010) causing neurological, pulmonary and abdominal pathologies.

Considering the importance of this species on human health, the objective of this work was to know the population structure of *L. fulica* in function of time and environmental variables in order to analyze and evaluate the establishment of the giant African snail population in Puerto Iguazú, Argentina.

Materials and methods

This study was carried out in Puerto Iguazú (25°36'39'' S, 54°34'49''W), Misiones Province, Argentina (Fig. 1). The climate in this region is subtropical, with a mean annual temperature of 21.2°C and an average annual rainfall of 1731 mm. The driest month is July (99 mm) whereas in October it is the maximum peak of precipitations (194 mm) (www.climate-data.org).

Samples of *L. fulica* were collected between October 2013 and November 2015. Sampling was done every two months (October-November, February-March and June-July) and they were called bimester, with intervals of two-month rest. The bimester were abbreviated as O-N, F-M and J-J. In each sampling all found specimens in the field during an interval of 15 minutes were collected by one person.

Mollusks were transferred alive in plastic vials to the laboratory. Snail shells were measured and separated into four equal size ranges (S): S1: 0.0 – 2.9 cm; S2: 3.0 – 5.9 cm; S3: 6.0 – 8.9 cm and S4: 9.0 – 12.0 cm.

The environmental variables temperature, humidity and rainfall were check out during each sampling (National Meteorological Service, Iguazú Air).

Correspondence analyses were done to observe the association between host size distribution in function of time (bimesters) and environmental variables. Analyses were done using Rstudio version 1.0.136 (RStudio Team, 2016).

Figure. 1. Puerto Iguazu area study.

Figura. 1. *Área de estudio en Puerto Iguazú.*

Results

A total of 995 *L. fulica* specimens were collected (Fig. 2). The frequency distribution of each ranges size in each bimester is shown in Table 1 and Fig. 1. It wasobserved that the number of total specimens collected was increasing towards the end of the investigation. Also, it is evident that S1 and S4 are the intervals less represented, whereas S2 and S3 are the most numerous, representing more than 80% of the samples (Table 1; Fig. 3).

The correspondence analyzes between size distribution (ordered for size in the second dimension) and bimester (environmental variables are represented in the first dimension) indicated that the smaller size S1 is associated with the bimester J-J, the intermediate size S2 is associated with the bimester O-N, and the largest sizes S3 and S4, are related with the bimester F-M (Fig. 4). The bimester and the size ranges are represented in the Figure 4 with a geometrical figure: black circle (bimester) and grey triangle (size ranges).

Figure. 2. *Lissachatina fulica.*

Figura. 2. Lissachatina fulica.

Table 1. Frequency distribution of each ranges size in function of the environmental variables in each bimester.

Tabla 1. *Distribución de frecuencias de cada intervalo de tamaño en función de las variables ambientales en cada bimestre.*

Ranges of size (cm)	O-N 2013	F-M 2014	J-J 2014	O-N 2014	F-M 2015	J-J 2015	O-N 2015	SubTotal
S1 0.0-2.9	n= 11	n= 8	n= 17	n= 39	n= 19	n= 65	n= 6	N= 165 P= 0.166
S2 3.0-5.9	n=37	n= 10	n= 15	n= 90	n= 53	n= 68	n= 217	N= 490 P= 0.492
S3 6.0-8.9	n= 18	n= 27	n= 22	n= 51	n= 101	n= 49	n= 51	N= 319 P= 0.32
S4 9.0-12	n= 1	n= 8	n= 1	n= 2	n= 4	n= 1	n= 4	N=21 P= 0.021
Subtotal	N= 67 P= 0.067	N= 53 P= 0.053	N= 55 P= 0.055	N= 182 P= 0.182	N= 177 P= 0.177	N= 183 P= 0.183	N= 278 P= 0.278	TOTAL 995

P= Proportion of snails by range size and by bimester; **n=** number of snail by range size vs bimester; **N=** subtotal of snails by range size and by bimester.

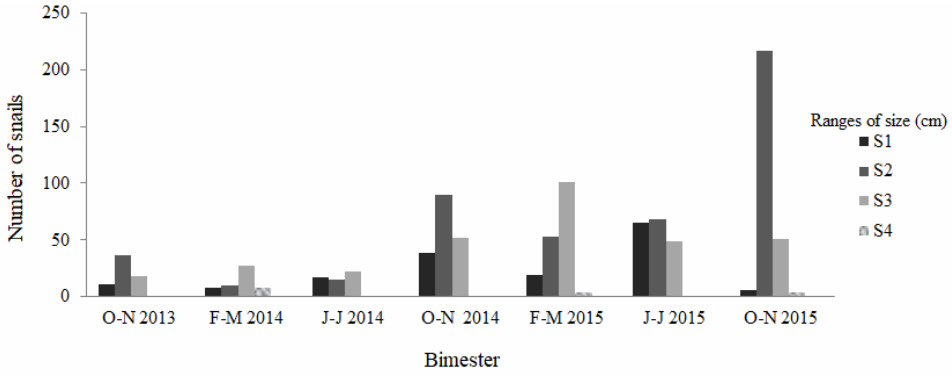

Figure. 3. Frequency distribution of each ranges size of *Lissachatina fulica* in Puerto Iguazú by bimester.

Figura. 3. *Distribución de frecuencias de cada intervalo de tamaño de* Lissachatina fulica *por bimestre en Puerto Iguazú.*

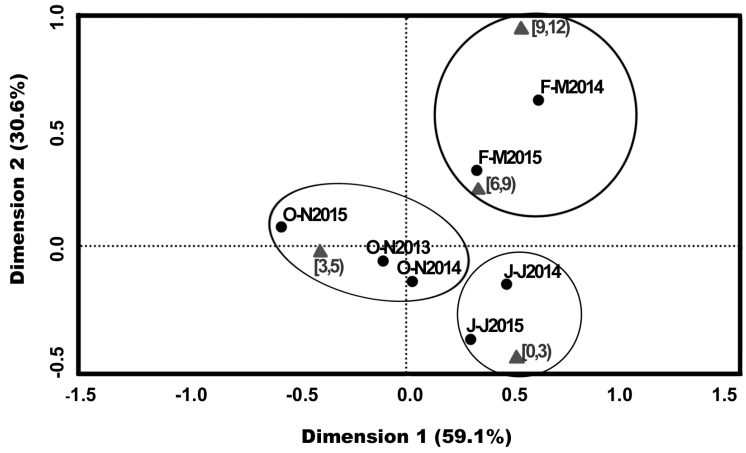

Figure. 4. Correspondence analyses between host size of *Lissachatina fulica* in Puerto Iguazú in function of time (bimesters) and environmental variables.

Figura. 4. *Análisis de correspondencia entre el tamaño del hospedador* Lissachatina fulica *en Puerto Iguazú, en función del tiempo (bimestres) y variables ambientales*.

Discussion

Previous studies have showed that the success of *L. fulica* as invasive species is due to several reasons: a) high reproduction rate, which generates explosive population growth in comparison with other terrestrial native snails; b) large number of eggs per oviposition (50-1000 eggs); c) polyphagous eating habits, and d) lack of natural enemies (Fischer & Costa, 2010).

The introduction of this mollusk species in Argentina probably responds to the nearness to Brazil and the frequent fishing practices (Valente *et al*., 2016). The proportions of size intervals in a population can indicate the degree of establishment of the giant African snail (Mead, 1961; Albuquerque *et al*., 2009) and allows to identify in which size range *L. fulica* has reached its sexual maturity. Simão & Fischer (2004) determined that four size ranges were established for the giant African snail in Brazil according to the length of the shell: immature (0-1cm), juvenile (1.1-4 cm), sub- adult (4.1-7 cm) and adult (7.1- ∞). The most frequent intervals in Bahia, Brazil were juvenile and sub-adult (Albuquerque *et al*., 2008). The same was observed in Puerto Iguazú, in were only few specimens of S4 (more than 9 cm) were found.

Lissachatina fulica has a gregarious behaviour that would favour the cannibalism among individuals of the same population and reduce the survival of smaller sizes individuals (Fischer & Colley, 2005; Fischer *et al*., 2006). Unlike the present study in which S1 were little represented, Gutiérrez Gregoric *et al*. (2013) registered sizes 0-4 cm as the mean interval in Corrientes province. The observed differences may be due because Gutierrez Gregoric *et al*. (2013) based their analysis on a single sampling conducting in May 2013. Avendaño & Linares (2015) suggest that the settling time of a population is reflected in the size of their specimens. It could be inferred that in those sites where larger specimens and different size intervals are represented, as in Puerto Iguazú, *L. fulica* population have a considerable time of establishment and species is well adapted, whereas in those areas in which small size predominate, the arrival is very new.

The body growth and biomass in *L. fulica* is influenced by environmental factors. Thus, climatic conditions can induce periods of lethargy, especially if the temperature and humidity reach low values. Once this lapse of time has passed, physiological changes that affect its development may appear in *L. fulica* (Albuquerque *et al*., 2009). In the present study, it was observed that the environmental conditions of the "wet season" favour the pickup of specimens, in where the sub-adult and adult stages (S2 and S3) are more representative. These snails have reached sexual maturity and are preparing to reproduction, having established some time ago in this environment. In contrast, during the "dry season", where there are scarce precipitations and low temperature, the immature and juvenile stages were the most abundant samples. It would be explained considering that the unfavourable environmental conditions determined the beginning of the hibernation period of the snails and they are buried and are difficult to find.

Present results indicated that *L. fulica* population is already established in Puerto Iguazú, showing the importance of incorporate management programs and control of this pest. Taking into account that the snails begins to be active after hibernation period in which temperature increase gradually, it would be the most appropriate moment to fight *L. fulica*.

Studies like the present can be important tools to establish strategies of control and management that do not affect other mollusk populations or pollute the natural environments, which are closely linked to human populations.

Acknowledgements

We wish to thank M. L. Morote (CEPAVE) for her help with the figures and Pilar Martínez (National Public Translator in English Language) for the English revision of the manuscript.

References

Acha, P. & B. Szyfres. 2003. Angiostrongyliasis, intestinal angiostrongyliasis, angiostrongyliasis (*Parastrongylus cantonensis)*. In: Pan American Health Organization (eds) Zoonoses and Communicable Diseases Man and Animals, Washington DC: PAHO, Scientific and Tech Publications Press. pp. 225-231.

Albuquerque, F.S., M.C. Peso-Aguiar & M.J. Assunção-Albuquerque. 2008. Distribution, feeding behavior and control strategies of

the exotic land snail *Achatina fulica* (Gastropoda: Pulmonata) in the northeast of Brazil. Brazilian Journal of Biology 68(4): 837-842.

Albuquerque, F.S., M.C. Peso-Aguiar, M.J.T. Albuquerque & L. Gálvez. 2009. Do climate variables and human density affect *Achatina fulica* (Bowdich) (Gastropoda: Pulmonata) shell length, total weight and condition factor? Brazilian Journal of Biology 69(3): 879-885.

Alicata, J.E. 1991. The discovery of *Angiostrongylus cantonensis* as a cause of human eosinophilic meningitis. Parasitolology Today 7(6): 151-153.

Ash, L. 1970. Diagnostic morphology of the third.stage larvae of *Angiostrongylus cantonensis*, *Angiostrongylus vasorum*, *Aelurostrongylus abstrusus*, and *Anafilaroides rostratus* (Nematoda: Metastrongyloidea). Journal of Parasitology 56(2): 249-253.

Avendaño, J.M. & E. Linares. 2015. Morfometría del caracol gigante africano *Achatina fulica* (Gastropoda: Achatinidae) en Colombia. Cuadernos de Investigación 7(2): 287-293.

Beltramino, A.A., R.E. Vogler, D.E. Gutiérrez Gregoric & A. Rumi. 2015. Impact of climate change on the distribution of a giant land snail from South America: predicting future trends for setting conservation priorities on native malacofauna. Climatic Change 131(4): 621-633.

Cross, J.H. 2007. The spread of angiostrongyliasis: the globetrotting rat lungworm. Southeast Asian Journal of Tropical Medicine and Public Health 38(1): 43-46.

Diaz, J.I., E. Lorenti, R. Valente, S. Capasso, D.E. Gutiérrez Gregoric & G.T. Navone. 2013. Estado actual del conocimiento de las parasitosis del molusco invasor *Achatina fulica* en la Argentina. Su importancia como posible hospedador intermediario de Angiostrongyliasis. In: Oscar Daniel Salomon (ed), Moluscos de Interés sanitario en la Argentina, Ministerio de Salud de la Nación, Buenos Aires. pp. 40-53.

Fischer, M.L. & E. Colley. 2005. Espécie Invasora em Reservas Naturais: Caracterizacao da Populaco de *Achatina fulica* Bowdich, 1822 (Mollusca – Achatinidae) na Ilha Rasa, Guaraquecaba, Paraná, Brasil. Biota Neotropica 5(1): 1-18.

Fischer, M.L., M. Simião, E. Colley, R. Dudeque Zenni, D.A. Teodoro da Silva & N. Latoski. 2006. O caramujo exótico invasor na vegetação nativa em Morretes, PR: diagnóstico da população de *Achatina fulica* Bowdich, 1822 em um fragmento de Floresta Ombrófila Densa aluvial. Biota Neotropica 6(2): 1-5.

Fischer, M.L. & L.C.M. Costa. 2010. O caramujo gigante africano *Achatina fulica* no Brasil. Editorial Champagnat Editora PUCPR, Curitiba, Brazil. 13-99 pp.

Franco-Acuña, D.O., J. Pinheiro, E.J.L. Torres, R.M. Lanfredi & S.V. Brandolini. 2009. Nematode cysts and larvae found in *Achatina fulica* Bowdich, 1822. Journal of Invertebrate Pathology. 100(2): 106-110.

Gutiérrez Gregoric, D.E., V. Nuñez, R.E. Vogler & A. Rumi. 2011. Invasion of the Argentinean Paranense rainforest by giant African snail, *Achatina fulica*. American Malacological Bulletin 29(1/2): 135-137.

Gutiérrez Gregoric, D.E., A. Beltramino, R. Vogler & A. Rumi. 2013. Expansión del rango de distribución de *Achatina fulica* (Gastropoda) y su concordancia con modelos predictivos. Amici Molluscarum 21(1): 17-21.

Lowe, S., M. Browne, S. Boudjelas & M. De Poorter. 2004. Cien de las especies Exóticas Invasoras más dañinas del mundo. Una selección del Global Invasive Species Database. Editorial School of Geography and Environmental Sciences (SGES), Nueva Zelanda. 11 pp.

Maldonado Júnior, A., R. Simoes, A.P. Oliveira, E. M. Motta, A.M. Fernandez, Z.M. Pereira, M.M. Monteiro, E.J. Lopes Torres & C.S. Thiengo. 2010. First report of *Angiostrongylus cantonensis* (Nematoda: Metastrongylidae) in *Achatina fulica* (Mollusca: Gastropoda) from Southeast and South Brazil. Memoria do Instituto Oswaldo Cruz 105(7): 938-941.

Matinella, L., G. Morales, C. Sierra, I. Silva & L. Pino. 2009. *Achatina fulica:* Un caracol de interés para la salud pública. Revista INIA HOY 6: 200-210.

Mead, A.R. 1961. Economic status. In: The University of Chicago Press (ed) The giant African snail; a problem in economic malacology University of Chicago Press. pp. 35-60.

Neto, N.A., R.A. Voeks, T.L. Días & R. Alves, 2012, Mollusks of Candomblé: symbolic and ritualistic importance. *Journal of Ethnobiology and Ethnomedicine*, 8(10): 1-10.

Oliveira, M.A., E. Torres, A. Maldonado Jr, J. Araujo, M. Fernandez, & C.S. Thiengo. 2010. *Achatina fulica* como hospedador intermediario de nematodes de interés sanitario-veterinario en Goias, Brasil. Revista de Patologia Tropical. 39(3): 199-210.

Raut, S.K. & G.M. Barker. 2002. *Achatina fulica* Bowdich and other achatinidae as a pests in tropicultural agriculture. Molluscs as Crop Pest. Editorial CABI Publishing, Wallingford. 55–114 pp.

RStudio Team, 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/. Versión 1.0.136.

Simão, S., & L. Fischer. 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 da Biodiversidade 4(2): 74-78.

Thiengo, C.S., A.F. Faraco, N.C. Salgado, R.H. Cowie & M.A. Fernandez. 2007. Rapid spread of an invasive snail in South America: the giant African snail *Achatina fulica*. Biological Invasions 9: 693-702.

Valente, R., J.I. Diaz, E. Lorenti, O.D. Salomón & G.T. Navone. 2016. Nematodes from *Achatina fulica* Bowdich, 1822 (Gasterópoda) in Argentina. Helminthologia 53(1): 109-112.

Recibido: 23 de marzo de 2020
Aceptado: 20 de agosto de 2020