Oecologia Australis
20(3): 391-395, 2016
10.4257/oeco.2016.2003.08

PREDATION ON NATIVE ANURANS BY INVASIVE VERTEBRATES IN THE ATLANTIC RAIN FOREST, BRAZIL

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Keywords: alien species; conservation; hotspot; non-native predators; novel negative interactions

Predation, one of the major and well-studied ecological interactions, may be defined as an organism killing another for nutritional purposes (Begon *et al.* 2006). This interaction is probably as old as life itself and has originated many times during the history of life (Bengtson 2002). Predator-prey interactions among dissimilar biological groups can be complex and difficult to understand clearly. The relationships between anurans and other vertebrates illustrate this point. Anurans are usually preyed upon by other vertebrates (Thurley & Bell 1994, Mesquita 2009), but in a few cases higher vertebrates serve as food for anuran species (Camilotti & Barreto-Lima 2011, Silva *et al.* 2011). This complexity in predator-prey interactions makes predicting the impacts of interactions difficult. The situation is even worse when we are dealing with novel interactions imposed by non-native species (Vitule & Prodocimo 2012, Saul & Jeschke 2015). When non-native predators are introduced into a new ecosystem, they may have dramatic effects on resident species, which have not co-evolved with the introduced ones, since they provide a new environmental stress (Salo *et al.* 2007, Caut *et al.* 2008, Paolucci *et al.* 2013, Saul & Jeschke 2015).

A common and widespread example is the common rat *Rattus rattus* (Linnaeus 1758), an opportunistic predator (Caut *et al.* 2008) that has been introduced onto several islands and continents, negatively interacting with native species (*e.g.*, Seto & Conant 1996, Caut *et al.* 2008). Similarly, certain fishes are frequently introduced into new environments, including Brazil and Paraná state, where many fish species have been widely introduced (*e.g.*, Vitule 2009, Lima-Junior *et al.* 2012, Pelicice *et al.* 2014, Daga *et al.* 2016). On the other hand, the establishment and the associated ecological effects caused by non-native species are poorly understood. The scarcity of studies and our consequent lack of understanding prevent us from taking the actions necessary to protect the native fauna into megadiverse places (Lövei *et al.* 2012). This is especially true in Neotropical regions and in ecosystems like the Brazilian Atlantic Rain Forest (BARF), an area of high biological diversity and relatively low investment in ecological research, especially in terms of determining the impacts of non-native species (Vitule 2009, Abilhoa *et al.* 2011). Moreover, the BARF is a biodiversity hotspot, and is considered one of the highest priorities for conservation action globally not only because of its high biodiversity and endemism, but also because of its current situation as a highly fragmented ecosystem (Myers *et al.* 2000, Ribeiro *et al.* 2009, Abilhoa *et al.* 2011). Therefore, in the present paper it is our intent to provide new data on novel predator-prey interactions involving native and non-native species in the BARF.

The first predatory event was recorded in video and photographed. It took place on the 19th of January 2012 in a residential yard bordered by the BAR in the municipality of Quatro Barras, state of Paraná (25°22'07.37"S, 49°03'55.65"W). We observed an individual of *R. rattus* attempting to prey on two individuals of the Yellow Cururu Toad *Rhinella icterica*

(Spix 1824), a male and a female. The common rat failed in the first attempt, and both the male and the female escaped. The female disappeared into the nearby vegetation while the male remained in the vicinity with its legs injured (apparently the left leg was broken) and venom extruding from its parotoid glands (Figure 1a), clearly showing distress. In a second attempt, the rat succeeded, dragging the toad into a hole by its hind legs (Figure 1b). After four hours of monitoring, the rat came out of the hole alone, so we assume the toad was killed.

Figure 1: a) Male *Rhinella icterica* after the first predatory attempt by *Rattus rattus* with injuries and exposed venom on the parotoid glands (arrows); b) *Rattus rattus* dragging toad into a hole in the second attempt.

The second predatory event was recorded during the analysis of the stomach contents of an individual of the black bass *Micropterus salmoides* (Lacépède 1802). The individual was collected in a lake in the municipality of Telêmaco Borba, state of Paraná, in December 2010, and was deposited in the ichthyology collection of Natural History Museum of the Capão da Imbuia (Individual number: MHNCI 12484). We found a tadpole of a tree frog of the genus *Hypsiboas* (Wagler 1830) (64.9 mm snout vent length, 2.34 g weight) among the stomach contents of the *M. salmoides*. The only study conducted with amphibians into such specific location (Machado 2004) indicates that there are about ten species of the genus in Telêmaco Borba.

Rats can cause major changes to the original natural species dynamics (Kurle *et al.* 2008). Taking into account the biological aspects of *R. rattus*, such as its generalist diet, fast reproduction (Clark & Price 1981), and current worldwide distribution in association with humans, it is likely that its negative effects on native species and ecosystems affect more than one trophic level. These same features allow it to adapt easily to new environments and make it difficult to eradicate (Major *et al.* 2006). Our record corroborates the important fact that rats present sophisticated and opportunistic behavior and are able to create novel interactions, so they may have impacts very difficult to predict.

Similarly, the black bass is an opportunistic predator that feeds primarily on other fish (Jackson 2002, Wasserman *et al.* 2011) but that, occasionally, may also include amphibians in their diet (Fuller *et al.* 1999, Froese & Pauly 2016). Predation pressure exerted by *M. salmoides* over amphibian populations (tadpoles and adults) has been reported for other countries (Hodgson & Hansen 2005, Wasserman *et al.* 2011), and may play a role in the reduction and local extinction of native frog populations, which then results in significant ecological impacts for the ecosystem (Britton *et al.* 2010, Gilliland 2010). We highlight that our record is the first one about predation by *M. salmoides* over amphibian into the Neotropics. Black bass is native to North America, but has been introduced to more than 50 countries, including Brazil, for sport fishing (Froese & Pauly 2016). It currently occupies fifth place among the most introduced species in inland waters (Welcomme 1992) and is listed as one of the 100 worst invasive alien species (Lowe *et al.* 2000). Ultimately, through cascading effects, introduced *M. salmoides* may change the water quality (Estes *et al.* 2011) and so indirectly affect amphibian populations (Gilliland 2010). In spite of all of the ecological risks related to *M. salmoides* and in spite of the fact that it has been introduced into Brazil for over 90 years, there are few studies that really measure its negative impact on Brazilian native communities and allow us to direct efforts at controlling its populations (Ribeiro 2013, Ribeiro *et al.* 2015).

Unfortunately, studies that focus on the negative impacts of non-native species are comparatively rare throughout the Neotropics (Vitule 2009, Vitule & Prodocimo 2012, Frehse *et al*. 2016). In general, non-native predators may have dramatic negative impacts on native species (Clout 2002, Caut *et al.* 2008, Saul & Jeschke 2015), but the magnitude of these impacts are rarely measured. Some review studies have described the potential predation of non-native species on native species (*e.g.*, Salo *et al.* 2007, Paolucci *et al.* 2013, Simberloff & Vitule 2014). According to these authors, non-native predators are likely to produce more severe impacts on prey than native predators. This seems to make sense when we consider that a prey species needs to interact with a new predator that it did not evolve with (Sih *et al.* 2010, Carthey 2014), so may be considered such as novel interaction. The consequences may be a disaster in such cases, as exemplified by the famous fate of the dodo bird, where rats played an important role predating the dodo's eggs (Hume 2006). Thus, the few studies concerning this subject allow us to assume that invasive species may cause even deeper impacts than we can notice, due to insufficient available data and measurements.

Non-native predators are one of the causes for amphibian population declines worldwide (Collins & Storfer 2003, Kats & Ferrer 2003), and the negative impacts of introduced vertebrates are probably more significant than we can detect (Clout 2002). Additionally, in Brazil, information about the impacts caused by introductions of non-native species is accumulating slowly (*e.g.*, Vitule 2009, Vitule & Prodocimo 2012, Frehse *et al*. 2016), because of gaps

in the basic information available for some species, including information on their occurrence and their interactions with native species. Therefore, basic bits of evidence, as the two cases reported here, are necessary and may contribute to our knowledge of the activities of non-native species. Additionally, they may serve as a starting point for future investigations that explore the novel interactions and negative impacts caused by invasive species. We must improve our knowledge base and provide data regarding non-native predator-prey interactions with a view to clarify their biological aspects and to enable species conservation.

ACKNOWLEDGMENTS

We thank to Carlos Eduardo Conte and Adriele K. C. de Oliveira for helping with identification and measurements of the tadpole, Marcos Valduga for collecting the specimen of *M. salmoides* and Dr. Jim Nienow for the English revision. ISO thanks to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq: 161812/2011-2) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES: 3855/13-9) for scholarships. JRSV thanks CNPq for providing the research productivity grants (CNPq: 303776/2015-3).

REFERENCES

Abilhoa, V., Braga, R. R., Bornatowski, H., & Vitule, J. R. S. 2011. Fishes of the Atlantic Rain forest streams: ecological patterns and conservation. In: O. Grillo & G. Venora (Eds.), Changing Diversity in Changing Environment. pp. 259–282. Croatia: InTech.

Begon, M., Townsend, C. R., & Harper, J. L. 2006. Ecology: from individuals to ecosystems. 4th ed. London, UK: Blackwell Science: p. 752.

Bengtson, S. 2002. Origins and early evolution of predation. In: P. H. Kelley & M. Kowalewski (Eds.), The fossil record of predation. pp. 289-317. Pittsburgh: Paleontological society.

Britton, J. R., Harper, D. M., Oyugi, D. O., & Grey, J. 2010. The introduced *Micropterus salmoides* in an equatorial lake: a paradoxical loser in an invasion meltdown scenario? Biological Invasions, 12(10), 3439–3448.

Camilotti, V. L., & Barreto-Lima, A. F. 2011. Ornithophagy in *Rhinella icterica* (Spix, 1824). Bioscience Journal, 27(6), 993–994.

Carthey, A. J., & Banks, P. B. 2014. Naïveté in novel ecological interactions: lessons from theory and experimental evidence. Biological reviews of the Cambridge Philosophical Society, 89(4) 932–949.

Caut, S., Angulo, E., & Courchamp, F. 2008. Dietary shift of an invasive predator: rats, seabirds and sea turtles. Journal of Applied Ecology, 45(2), 428–437.

Clark, B. R., & Price, E. O. 1981. Sexual maturation and fecundity of wild and domestic Norway rats (*Rattus norvegicus*). Journals of Reproduction and Fertility, 63(1), 215–220.

Clout, M. 2002. Biodiversity loss caused by invasive alien vertebrates. Zeitschrift für Jagdwissenschaft, 48(Supplement 1), 51–58.

Collins, J. P., & Storfer, A. 2003. Global amphibian declines: sorting the hypotheses. Diversity and Distribution, 9(2), 89–98.

Daga, V. S., Debona, T., Abilhoa, V., Gubiani, E. A., & Vitule, J. R. S. 2016. Non-native fish invasions of a Neotropical ecoregion with high endemism - a review of the Iguaçu River. Aquatic Invasions, 11(2), 209–223.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., Carpenter, S. R., Essington, T. E., Holt, R. D., Jackson, J. B. C., Marquis, R. J., Oksanen, L., Oksanen, T., Paine, R. T., Pikitch, E. K., Ripple, W. J., Sandin, S. A., Scheffer, M., Schoener, T. W., Shurin, J. B., Sinclair, A. R. E., Soulé, M. E., Virtanen, R., & Wardle, D. A. 2011. Trophic downgrading of Planet Earth. Science, 333(6040), 301–306.

Frehse, F. A., Braga, R. R., Nocera, G. A., & Vitule, J. R. S. 2016. Non-native species and invasion biology in a megadiverse country: scientometric analysis and ecological interactions in Brazil. Biological Invasions, 1–13. DOI: 10.1007/s10530-016-1260-9

Froese, R., & Pauly, D. 2016. FishBase: World Wide Web electronic publication. Version 10/2015. Retrieved from http://www.fishbase.org

Fuller, P. L., Nico, L. G., & Williams, J. D. (Eds.). 1999. Nonindigenous fishes introduced into inland waters of the United States. Maryland: American Fisheries Society: p. 622.

Gilliland, K. L. 2010. The presence of *Micropterus salmoides* (Largemouth Bass) influences the populations of *Rana draytonii* (California redlegged frog) and *Pseudacris regilla* (Pacific tree frog) in two ponds in Santa Barbara county, California. Faculty of California State Polytechnic State University. p. 100

Hodgson, J. R., & Hansen, E. M. 2005. Terrestrial prey items in the diet of Largemouth Bass, *Micropterus salmoides*, in a small North temperate lake. Journal of Freshwater Ecology, 20(4), 793–794.

Hume, J. 2006. The history of the Dodo *Raphus cucullatus* and the penguin of Mauritius. Historical Biology, 18(2), 65–89.

Jackson, D. A. 2002. Ecological effects of *Micropterus* introductions: the dark side of black bass. In: D. P. Philipp & M. S. Ridgway (Eds.), Black bass: Ecology, conservation, and management. pp. 221–232. Maryland: American Fisheries Society.

Kats, L. B., & Ferrer, R. P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distribution, 9(2), 99–110.

Kurle, C. M., Croll, D. A., & Tershy, B. R. 2008. Introduced rats indirectly change marine rocky intertidal communities from algae to invertebrate-dominated. Proceedings of the National Academy of Science, 105(10), 3800–3804.

Lima-Junior, D. P., Pelicice, F. M., Vitule, J. R. S., & Agostinho, A. A. 2012. Aquicultura, política e meio ambiente no Brasil: Novas propostas e velhos equívocos. Natureza & Conservação, 10(1), 88–91.

Lövei, G. L., Lewinsohn, T. M., Dirzo, R., Elhassan, E. F., Ezcurra, E., Freire, C. A., Gui, F. R., Halley, J. M., Tibazarwa, J. M., Jiang, M. X., Katebaka, R., Kinyamario, J., Kymanywa, S., Liu, F. Q., Liu, S. S., Liu, W. X., Liu, Y. Q., Lu, B. R., Minot, E. O., Qiang, S., Qiu, B. L., Shen, H., Soberon, J., Sujii, E. R., Tang, J. W., Uludag, A., Vitule, J. R. S., Wan, F. H., Wang, F. H., Yang, G. Q., Zhang, X. Y., & You, M. S. 2012. Megadiverse developing countries face huge risks from invasives. Trends in Ecology & Evolution, 27(1), 2–3.

Lowe, S., Browne, M., Boudjelas, S., & De Poorter, M. 2000. 100 of the world's worst invasive alien species: A selection from the global invasive species database. 12p. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). Retrieved from http://www.issg.org/pdf/publications/worst_100/english_100_worst.pdf

Machado, R. A. 2004. Ecologia de assembléias de anfíbios anuros no município de Telêmaco Borba, Paraná, sul do Brasil. Programa de Pós-Graduação em Zoologia da Universidade Federal do Paraná. p. 113.

Major, H. L., Jones, I. L., Charette, M. R., & Diamond, A. W. 2006. Variations in the diet of introduced Norway rats (*Rattus norvegicus*) inferred using stable isotopes analysis. Journal of Zoology, 271(4), 463–468.

Mesquita, P. C. M. D. 2009. A Record of predation on a poisonous toad *Rhinella granulosa* (Anura, Bufonidae) by Guira Cuckoo *Guira guira* (Cuculidae, Crotophaginae) in the state of Ceará, Brazil. Revista Brasileira de Ornitologia, 17(1), 84–85.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature, 403(6772), 853–858.

Paolucci, E. M., MacIsaac, H. J., & Ricciardi, A. 2013. Origin matters: alien consumers inflict greater damage on prey populations than do native consumers. Diversity and Distributions, 19(8), 988–995.

Pelicice, F. M., Vitule, J. R. S., Lima, D. P., Orsi, J. M. L., & Agostinho, A. A. 2014. A Serious New Threat to Brazilian Freshwater Ecosystems: The Naturalization of Nonnative Fish by Decree. Conservation Letters, 7(1), 55–60.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. 2009. The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation, 142(6), 1141–1153.

Ribeiro, V. M. 2013. *Micropterus salmoides*, um predador introduzido em um reservatório Neotropical: composição da dieta, táticas reprodutivas e métodos de captura. Pós-Graduação em Ecologia e Conservação da Universidade Federal do Paraná. p. 112.

Ribeiro, V. M., Braga, R. R., Abilhoa, V., & Vitule, J. R. S. 2015. Evaluation of three capture techniques for invasive *Micropterus salmoides* (Lacépède, 1802) in a Neotropical reservoir: Implications for population control and management. Journal of Applied Ichthyology, 31(6), 1127–1129.

Salo, P., Korpimäki, E., Banks, P. B., Nordström, M., & Dickman, C. R. 2007. Alien predators are more dangerous than native predators to prey population. Proceedings of the Royal Society B, 274(1615), 1237–1243.

Saul, W-C., & Jeschke, J. M. 2015. Eco-evolutionary experience in novel species interactions. Ecology Letters, 18(3), 236–245.

Seto, N. W. H., & Conant, S. 1996. The effects of rats (*Rattus rattus*) predation on the reproductive success of Bonin petrel (*Pterodroma hypoleuca*) on Midway Atoll. Journal of Colonial Waterbirds Society, 19(2), 171–322.

Sih, A., Bolnick, D. I., Luttbeg, B., Orrock, J. L., Peacor, S. D., Pintor, L. M., Preisser, E., Rehage, J. S., & Vonesh, J. R. 2010. Predator-prey naïveté, antipredator behavior, and the ecology of predator invasions. Oikos, 119(4), 610–621.

Silva, E. T., Ribeiro-Filho, O. P., & Feio, R. N. 2011. Predation of native anurans by invasive Bullfrogs in Southeastern Brazil: spatial variation and effect of microhabitat use by prey. South American Journal of Herpetology, 6(1), 1–10.

Simberloff, D., & Vitule, J. R. S. 2014. A call for an end to calls for the end of invasion biology. Oikos, 123(4), 408–413.

Thurley, T., & Bell, B. D. 1994. Habitat distribution and predation on a western population of terrestrial *Leiopelma* (Anura: Leiopelmatidae) in the northern King County, New Zealand. New Zealand Journal of Zoology, 21(4), 431–436.

Vitule, J. R. S. 2009. Introdução de peixes em ecossistemas continentais brasileiros: revisão, comentários e sugestões de ações contra o inimigo quase invisível. Neotropical Biology and Conservation, 4(2), 111–122.

Vitule, J. R. S., & Prodocimo, V. 2012. Introdução de espécies não nativas e invasões biológicas. Estudos de Biologia, 34(83), 225–237.

Wasserman, R. J., Strydom, N. A., & Weyl, O. L. F. 2011. Diet of Largemouth Bass, *Micropterus salmoides* (Centrarchidae), an Invasive Alien in the Lower Reaches of an Eastern Cape River, South Africa. Zoological Society of Southern Africa, 46(2), 378–386.

Welcomme, R. L. 1992. A history of international introductions of inland aquatic species. ICES Marine Science Symposium, 194, 3–14.

Submitted: 16 June 2015
Accepted: 11 April 2016