



Fig. 1: The three invasive species with greatest impacts displaying some of the results of the Generic Impact Scoring System (GISS). Photographs (from left to right) by Brian Fisher, Alex Rebelo and Jose Martinez.

Assessing the Impacts of Invasive Amphibians

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The world has entered an era of globalization, with a greater volume of goods being traded and at further distances than ever before. This has dramatically increased the chances of introducing and spreading exotic species with cargo, causing a rising number of documented alien invasions (1). The major concern with invasive species is their negative impact on the natural environment and human activities. If the impact is expected to be extremely detrimental, an eradication program can exterminate the invasive population. But eradication is very costly, especially when trying to avoid collateral damage to the surrounding environment. Therefore, it is easy to see the value of being able to predict impacts of invasive species before prioritizing action.

The problem is that, although impacts for invasive amphibians are known, there is currently no way to compare them between species, or for that matter between a potentially invasive frog and a mammal or bird. But we need to make informed decisions as soon as possible, preferably before the aliens become well established. For example, if an alien toad is introduced to an area, should we use all our resources to exterminate it, or should we spread our resources to other invasive species already established or that might easily be introduced? Presumably this decision should depend on their relative impacts. This is becoming even more relevant as the number of introduced species increases. We decided to start tackling this problem with a review of all published literature on invasive amphibian impacts, and to assess them using an impact scoring system (2).

We used the generic impact scoring system (GISS) framework, essentially a score-sheet that lets one categorize an impact and its

severity. This is a standardized method that has already been used on other invasive animals in Europe (3), and allows a comparison across other groups, not only amphibians. We used Kraus's book of global amphibian introductions (4) to identify which species have been introduced outside of their native ranges. With this information about species and places of introduction we could systematically search with Google Scholar for literature investigating invasive impacts. Each relevant paper was scanned to determine whether it reported any kind of environmental or socio-economic impact.

GISS splits environmental impacts into competition, predation, spread of disease, herbivory and hybridization. Socio-economic impacts (those that affect humans) include damage to farming, impacts on infrastructure and even influences on human health or social life. Severity of the impact was scored between 0 (no impact) and 5 (highest possible impact), using pre-determined severity criteria for each impact category. This was quite a task to complete for 104 species even with dividing the work between a team of seven.

Reviewing published literature can be a long and tedious process, but it can also be highly rewarding. During this process we discovered some of the interesting impacts that amphibians could have on people. One particularly shocking discovery was the resting locations of the Cuban Tree Frog (*Osteopilus septentrionalis*) in Florida. This species prefers to hide in sheltered areas, including man-made objects, with the occasional result of transformer destruction followed by power-cuts (5). In another case, an invasion of toxic Asian Toads (*Duttaphrynus melanostictus*) in Indonesia, caused poisoning of unsuspecting villagers and the death of at least one child (6). In Hawaii, the invasive Coqui Frog (*Eleutherodactylus coqui*) call so loudly at night that residents are unable to sleep, causing property prices to drop in invaded areas (7).

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While these socio-economic impacts were certainly interesting, they were few and far between. The majority of documented impacts were on the natural environment. The impacts with the highest severity were hybridization, followed by predation, disease, competition and herbivory. While by far the most common documented impact of invasive amphibian species was predation, including frogs eating frogs (8). In comparison with other vertebrate groups, we found that invasive amphibians had impacts comparable to fish and birds, but lower than that of mammals. Proportionately however, far fewer amphibian species have impacts than in other groups. This suggests that studies investigating amphibian impacts are lacking, possibly because they are overlooked as a serious threat. We show that this is not true and that they deserve more attention in future.

So which invasive amphibians are the “biggest and baddest”? Previously, several amphibians were included amongst the a list of the “100 worst invaders” (9), but now using the GISS system, we were able to compare all amphibian species. In third place is the Asian Toad (*Duttaphrynus melanostictus*), which has a lower environmental impact than some other candidates, but has significant socio-economic impacts (Fig. 1). In second place is the African Clawed Frog (*Xenopus laevis*), which has an impressive introduced range (almost everywhere) and a ferocious appetite so that it literally eats its way through many aquatic ecosystems. In first place, hands down, is the Cane Toad (*Rhinella marina*), which has invasive populations best studied in Australia, but present in at least another 38 countries (4). This large toad is reputed to eat anything that fits within its mouth, while also possessing a toxin not natural to native Australian predators. As a result, it causes tremendous impacts both above and below its food chain, affecting biodiversity as well as a number of economic activities.

Amphibian invaders can be major players in the ecosystem, and with increasing rates of introductions and dwindling natural areas we need to be on our guard. Keep a look out for invasive amphibians and report any impacts or suspicious individuals to your local authorities. Try joining a citizen scientist initiative in your area (such as iSpot or iNaturalist) where you can share your findings as well as contribute valuable information about native amphibians.

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References:

1. P. E. Hulme, *Journal of Applied Ecology*, **46**(1), 10–18 (2009).
2. G. J. Measey et al., *Diversity and Distributions* (in press), doi:10.1111/ddi.12462.
3. S. Kumschick et al., *Journal of Applied Ecology*, **52**(3), 552–561 (2015).
4. F. Kraus, *Alien reptiles and amphibians: a scientific compendium and analysis* (Springer, New York, 2009).
5. S. Johnson, *The Cuban Treefrog (*Osteopilus septentrionalis*) in Florida* (Publication WEC, 2007).
6. C. Trainor, *Survey of a population of black-spined toad *Bufo melanostictus* in Timor-Leste: confirming identity, distribution, abundance and impacts of an invasive and toxic toad* (Charles Darwin Univ., AusAID, 2009).
7. B. A. Kaiser, K. M. Burnett, *Interdisciplinary Environmental Review*, **8**, 1–11 (2006).
8. G. J. Measey et al., *PeerJ*, **3** (2015).
9. S. Lowe, M. Browne, S. Boudjelas, M. De Poorter, 100 of the world’s worst invasive alien species: A selection from the global invasive species database (Invasive Species Specialist Group, Auckland, 2000).



The outcome of a predation attempt by an Australian goanna on the invasive Cane Toad (*Rhinella marina*). The bufotoxins secreted by Cane Toads are unfamiliar to Australian predators and many succumb to poisoning, causing major impacts on predator populations. Photo: Thomas Madsen.