*Rev. sci. tech. Off. int. Epiz.*, 2010, **29** (2), 235-240

# Invasive reptiles and amphibians

F. Moutou [(1)] & P.-P. Pastoret [(2)]

(1) Agence Française de Sécurité Sanitaire des Aliments (AFSSA), Laboratoire d'Etudes et de Recherches en Pathologie Animale et Zoonoses (LERPAZ), 23 Avenue du Général-de-Gaulle, 94706 Maisons Alfort, France
(2) World Organisation for Animal Health (OIE), 12 Rue de Prony, 75017 Paris, France

**Summary**

Although they are frequently lumped together, reptiles and amphibians belong to two very different zoological groups. Nevertheless, one fact is clear: while numerous reptile and amphibian species on Earth are in decline, others have taken advantage of trade or human movements to become established in new lands, adopting different, and sometimes unusual, strategies. The authors have taken a few examples from these two zoological groups that illustrate the majority of cases. A brief analysis of the causes and effects of their introductions into new areas reveals connections with economic interests, trade in companion animals, medical research and public health.

**Keywords**

African clawed frog – Amphibian – Brown tree snake – Bullfrog – Cane toad – Cuban tree frog – Green iguana – Red-eared slider – Reptile.

## Introduction

Although they are frequently lumped together, reptiles and amphibians (or batrachians) belong to two quite distinct groups of vertebrate (2, 9, 11). The study of reptiles is known as herpetology and the study of amphibians is called batrachology, although the term herpetology is commonly used to include amphibians too (whether it should be is debatable) (7). Amphibians have a number of very unusual characteristics. It is perhaps among this group of vertebrates that the passage from aquatic life to life on land, from gill to lung, took place. Doubtless it was the observation of tadpoles metamorphosing into frogs that prompted the vocation of many a biologist, not to mention a fair number of veterinarians. Amphibians have also provided (and still provide) biological material for the laboratory. Work on embryology, fertilisation, monitoring the first few divisions of the fertilised egg and subsequent stages in embryo development, owes much to amphibians. Reproductive strategies within the amphibian group range from species that lay their eggs solely in water to those that dispense with the spawning phase altogether and only require a moist place to lay their eggs. Neoteny was discovered in a salamander, for instance. Today, the entire group is facing two totally opposing situations. On the one hand, it was recently discovered that the specific diversity of amphibians had been severely underestimated. An amazing number of new taxa have been described in recent years, with the number of known species practically doubling in barely two decades, bringing the total to well over 6,000 (8). On the other hand, the group as a whole is undergoing a severe loss of biodiversity, a phenomenon apparently unique to them, perhaps precisely because of their unusual characteristics (14, 18, 19). The decline in amphibians, for whatever reason, is a subject of research and concern. Ascertaining whether the *Batrachochytrium dendrobatidis* fungus is a cause or an effect, a culprit or merely a witness, does nothing to change the steep decline in the entire taxon. However, despite this decline a few species have successfully expanded outside their native range, providing us with examples of their own particular methods of biological invasion.

The reptile group brings together a number of species that do, of course, have points in common, but that also have a number of differences. Modern taxonomy has taught us that the group, which includes turtles, crocodiles, tuataras, lizards and snakes, is both heterogeneous and polyphyletic.

The authors take a few examples from each group to illustrate the biological invasion contexts in which they are present and actively involved, by analysing the causes, means of introduction and associated consequences. This is by no means a comprehensive review of the subject.

# Reptiles

## Red-eared slider

The red-eared slider (*Trachemys scripta*) (Fig. 1) is one of the best-known models of an invasive species (2, 6, 11, 17). It is recognised by the red markings on either side of the head, which may be missing in some individuals. The shell can grow as long as 30 cm in an adult, while the largest can span 60 cm in total length. The red-eared slider is an aquatic turtle that was sold widely as a companion animal during the latter half of the 20th Century, in the form of very young and very small individuals. It became established in a host of countries when the owners, taken aback at its growth and voracious appetite, decided to release their troublesome pet into the wild. The red-eared slider, which originates from the eastern United States, is very adaptable and can cope with a wide range of climates, temperatures and habitats, feeding and reproducing easily. In many regions, it has become a competitor to local aquatic turtle species, such as the European pond turtle (*Emys orbicularis*), which shares the same habitats on the European continent. It is not known for certain how the cohabitation of these two species will evolve in the long term. To tackle the excessive number of abandonments in the natural environment, the European Union banned the importation of the red-eared slider in 1997, but other commercial species have come to take its place, as demand has remained steady. Between 1989 and 1997, an estimated 52 million individuals had been exported from the United States to Europe and Asia. While the introduction of red-eared slider into Europe was solely for the companion animal market, in Asia the animals were also sold for human consumption. Given that this turtle is a classical reservoir of salmonella, further measures have been taken to control its trade on health grounds. This health risk led the United States to ban its sale throughout the country as from 1975 (6).

## Green iguana (or common iguana)

The green iguana, or common iguana (*Iguana iguana*), is a large, herbivorous, tree-dwelling reptile from South America, which is also commonly sold in pet shops just about everywhere in the world. The largest can grow up to 2 m long, one-quarter of which represents the body and the remainder the tail, with such individuals weighing more than 3 kg. Another species also exists, the Lesser Antillean iguana (*Iguana delicatissima*) (Fig. 2), which is endemic to several islands in the Antilles archipelago. The Lesser Antillean iguana is a little smaller and more heavily built than the green iguana (measuring 140 cm to 150 cm in total length, but weighing the same), and has a different body/tail ratio (one-third body, two-thirds tail, although variations exist). Trade in exotic companion animals brought the green iguana to the islands inhabited by the Lesser Antillean iguana, enabling the green iguana to found a line there when it was released into the wild or escaped from captivity. Experience has shown that the green iguana can interbreed with the local Lesser Antillean iguana. Demographic pressure appears to favour the introduced species, which could ultimately replace the Lesser

**Fig. 1**
**Red-eared slider (*Trachemys scripta*), Tenerife, Canary Islands**
A model invasive species associated with trade in companion animals
© V. Besnard & F. Moutou

**Fig. 2**
**Lesser Antillean iguana (*Iguana delicatissima*), St Barthelemy, Lesser Antilles**
Under threat from the introduced South American green iguana (*Iguana iguana*)
© V. Besnard & F. Moutou

Antillean iguana altogether on all the islands where it is currently present (4). So, in this case of invasion, the impact is on biodiversity.

### Brown tree snake

The brown tree snake (*Boiga irregularis*), which was introduced onto the Pacific island of Guam in a shipment of goods, probably in around 1950, is a textbook example of the potential impact of an introduction; indeed, all texts on biological invasions cite it (21). The species is native to northern Australia, eastern Indonesia, New Guinea and the Solomon Islands. The brown tree snake is agile, tree-dwelling and venomous (although its poison is rarely fatal to humans), and can grow up to 3 m long. On the island of Guam, which has a surface area of 541 $km^2$ (approximately 50 km long by 10 km wide) and which was already much altered as a combined result of deforestation, the introduction of rats (*Rattus* spp.) and a development model that is not always environmentally-friendly, the brown tree snake has been directly involved in the extinction of 10 bird species out of the 12 indigenous forest bird species that still existed on Guam when the snake was introduced onto the island. Of the remaining two species, one appears to have withstood the onslaught, but the second is on the brink of extinction. Even though the rat population would seem to have diminished, again because of the snake, this is small consolation. In this case, too, the impact of the invasion is measured mainly in terms of biodiversity loss.

## Amphibians

### Bullfrog

The bullfrog (*Lithobates catesbeianus*) is the largest frog native to North America. Its body can measure up to 20 cm in length and its average weight is close to 500 g (6, 9). It was probably on account of its size that it was first introduced into breeding farms in a number of countries, either as a meat animal or a companion animal, and was thus enabled to become established in new territories. Its arrival in south-western France can perhaps be attributed to a traveller from the United States deliberately releasing bullfrog eggs, tadpoles or juvenile frogs into the wild (15). The bullfrog seems capable of spreading rapidly in the colonised area, although it is difficult to ascertain whether the spread is spontaneous or whether it is aided intentionally or accidentally by humans. Its large size makes the bullfrog a potential predator of smaller local amphibian species, but the consequences of this aggressive cohabitation are as yet unknown. The species is also suspected of carrying the *Batrachochytrium dendrobatidis* fungus and, perhaps, in this way, contributing to the global decline of amphibians (10). In many cases, lack of data predating the bullfrog's introduction makes it tricky to confirm this hypothesis. After being introduced into the United Kingdom, it was deliberately eradicated. The estimated cost of that operation was £29,000. Although France has also adopted an official eradication programme, it is not certain to succeed. The bullfrog could persist in the rest of Europe. If this is this case, several potential risks may be envisaged, but the effects are still difficult to measure objectively.

### Cuban tree frog

The Cuban tree frog (*Osteopilus septentrionalis*) illustrates another potential type of amphibian introduction. The species is rather large for a tree frog (9 cm to 14 cm). It must have arrived in the Lesser Antilles comparatively recently, around 1980 (4). Its native home does in fact seem to be Cuba, but it may also originate from the Bahamas. As the Cuban tree frog has already been moved quite extensively, it is difficult to pinpoint its historical natural range. It appears to have been introduced into the islands of St Martin and St Barthelemy, in the northern Antilles chain, with imported plants for garden centres. Once imported, the species appears to be capable of establishing a line if the small initial population is sufficient, or if there are repeated introductions on a regular basis. On other islands in the Antilles where the Cuban tree frog has been introduced, it has become a predator of a small species (3 cm to 5 cm) of tree-dwelling frog (*Eleutherodactylus* spp.), an endemic form of which is present on each individual island or group of islands. It poses a clear threat to local biodiversity. It is clear, then, that this movement of Cuban tree frogs in conjunction with the trade in exotic plants poses biodiversity problems.

### African clawed frog

The African clawed frog (*Xenopus laevis*) is a fully aquatic amphibian that originated in sub-Saharan Africa (9, 12). It has rather a curious morphology, aptly illustrating its various adaptations to underwater living conditions. It measures between 8 cm and 12 cm in length. Its tadpole looks very much like a small fish and is equipped with barbels. This frog has been used in laboratories since the mid-20th Century, for two major reasons: to conduct research into developmental biology and as a pregnancy test for women (if the frog produced eggs after injection with serum or urine from the patient, the test was positive). It has already escaped from captivity in the United States, Chile, the United Kingdom and Indonesia. As it is considered to be a tropical species, it was not thought possible for it to acclimatise in cooler climates, but that is exactly what it has done in recent years in France, where a population now seems to have become established in the west and central regions of the country. The animals clearly originated from a former breeding centre situated in the area, which, before being closed, supplied laboratories. The clawed frog's presence in the wild was discovered in 1998. This was when it became apparent that it had an eclectic diet, reproduced easily in the wild and that it was very much at home in the ponds of the local landscape of hedged farmland. It is still too early to assess the impact of its presence in this French region. However, preliminary data indicate a decline in the specific diversity of colonised ponds compared with that of non-colonised ponds. The origin of this species, as escapees from research centres, makes it a little more unusual than the other amphibians mentioned. Nevertheless the potential consequences are just the same.

### Cane toad (or giant toad)

A native of Central and South America, the cane toad, or giant toad (*Bufo marinus*) (Fig. 3), is a large amphibian that can exceed 20 cm in length and weigh more than 1 kg (3, 4, 20). It was introduced into several countries in the early 20th Century as a means of biological control against various crop insect pests. It was introduced into Australia in 1935 to control two sugar cane pests, the greyback cane beetle (*Dermolepida albohirtum*) and the frenchie beetle (*Lepidiota frenchi*). In a previous attempt in Puerto Rico, the use of the cane toad as a biocontrol agent had been a confirmed success as the pest's biology exposed it to the toad. Unfortunately, the lifecycle of Australia's native greyback cane beetle and frenchie beetle shielded them to a large extent from the introduced predator, which promptly turned to a whole host of other prey, including some rare and protected species. In Australia, the cane toad has therefore become a pest, having expanded its geographical range significantly from its points of entry around Cairns, Innisfail, Mackay and Bundaberg, where Queensland's sugar cane plantations are located. The cane toad is a prime example of adaptability, aided by its parotid glands, which produce a toxic secretion that repels numerous potential predators. This has safeguarded it from many Australian carnivores. There are estimated to be more than 100 million cane toads in Australia and their range is thought to be expanding by between 30 km and 50 km a year. Their density can be as much as 2,000 individuals per $km^2$. It is the only amphibian known to be able to operate along the seashore, hence its scientific name. Control methods are commensurate with the scale of the threat and have therefore intensified since the Australian government declared it a harmful species in 2005. The State of Western Australia financed a control programme worth AUS$2.5 million in July 2005. The introduction of this species has now become a nationwide problem.

**Fig. 3**
**Cane toad (*Bufo marinus*), Queensland, Australia**
A native of the Americas, originally introduced for biological pest control but now considered a nuisance
© V. Besnard & F. Moutou

## Conclusion

These are only a few of the many examples of invasive reptiles and amphibians (13). Nevertheless, the causes and effects associated with their movements tend to be common to both groups. Certain species are sought after as companion animals and are often bred by terrarium enthusiasts, which does not preclude escape from captivity. Although trade for human consumption can sometimes be the reason for introducing reptiles and amphibians, it is not the most typical one. The accidental transport of eggs, larvae or adults (Fig. 4), depending on the biology of the different species, has led to some astonishing adaptations by these animals, some of which are totally aquatic, some terrestrial and others tree-dwelling. A more unusual source of invasion is the escape of animals from laboratories or universities. This is the case with numerous green frog populations of the *Rana* genus (subgenus *Pelophylax*) in Europe, which were sometimes released or escaped, a long way from the areas where they had been collected. Little is known about the impact, in terms of genetic admixture between populations or species, because it has not been monitored, while the genetics of these species obey highly unusual models of natural hybridisation without the original wild stock dying out (2, 15).

There are two types of consequence. Some introductions appear to have caused no spectacular effects, such as the introduction of the Mediterranean tree frog (*Hyla meridionalis*) into the Canary Islands and Madeira (Fig. 5) (2), or of certain African amphibian species into the Mascarene Islands (5) – all of these islands were initially devoid of amphibians. However, this may only be because the studies have not been exhaustive enough. Monitoring of invertebrates (the usual prey of reptiles and amphibians) is often far less thorough than that of vertebrates (16).

**Fig. 4**
**House gecko (*Hemidactylus* sp.), Sulawesi, Indonesia**
This anthropophilic little gecko is adept at hopping by boat from island to island; its eggs, which stay glued to their support, are well adapted to such journeys


**Fig. 5**
**Mediterranean tree frog (*Hyla meridionalis*), Tenerife, Canary Islands**
Introduced into continental Europe probably by accident


Other introductions, however, are less low-profile, involving not just the largest species. Loss of biodiversity is still the usual consequence of biological invasions, bringing with it the associated problems of competition. In addition to these consequences is the problem of the passive transport of pathogens. The case of the *Batrachochytrium dendrobatidis* fungus is cited regularly (10), and there is also the transport of salmonella strains. In the latter case, the consequences are more in the realm of public health and concern chiefly companion reptiles and amphibians. There is copious literature on the subject, although it tends to take the form of descriptions of outbreaks or small epidemics, rather than of more general overviews. In the United States alone, salmonella infections associated with reptiles and amphibians are estimated to cause around 74,000 human cases a year out of a total of nearly 1.4 million salmonella cases, all causes combined, resulting in 15,000 hospitalisations and 400 deaths (1).

Nevertheless, all this should not make us lose sight of the unfavourable global status of numerous reptile and amphibian species. The worldwide decline in the number of amphibians is currently one of the chief concerns of biologists and ecologists. A more in-depth understanding of this decline is likely to further our knowledge of the functioning of the Earth's ecosystems, and hence the impact of human activities on our own environment.

■

# References


1. Anon. (2010). – Multistate outbreak of human *Salmonella* Typhimurium infections associated with aquatic frogs – United States, 2009. *MMWR*, **58** (51 & 52), 1433-1436.

2. Arnold N. & Ovenden D. (2004). – Le guide herpéto. 199 amphibiens et reptiles d'Europe. Delachaux et Niestlé, Paris, 288 pp.

3. Boll V. (2006). – L'avancée alarmante du crapaud des cannes en Australie. *Le Courrier de la Nature*, **230**, 121-213.

4. Breuil M. (2002). – Histoire naturelle des amphibiens et reptiles terrestres de l'archipel guadeloupéen. Muséum National d'Histoire Naturelle, Paris, 344 pp.

5. Cheke A. & Hume J. (2008). – Lost land of the dodo. T. & A.D. Poyser, London, 464 pp.

6. Delivering Alien Invasive Species Inventories for Europe (DAISIE) (2009). – Handbook of alien species in Europe. Invading nature: Springer series in invasion ecology, Vol. 3. Springer, Netherlands, 399 pp.

7. Dubois A. (1991). – Batrachology as a distinct scientific discipline. *Alytes*, **9** (1), 1-14.

8. Dubois A. (2008). – I had a dream. *Alytes*, **25** (3-4), 89-92.

9. Duguet R. & Melki F. (eds) (2003). – Les amphibiens de France, Belgique et Luxembourg. Collection Parthénope, Biotope, Mèze, 480 pp.

10. Garner T.W., Perkins M.W., Govindarajulu P., Seglie D., Walker S., Cunningham A.A. & Fisher M.C. (2006). – The emerging amphibian pathogen *Batrachochytrium dendrobatidis* globally infects introduced populations of the North American bullfrog, *Rana catesbeiana. Biol. Lett.*, **2**, 455-459.

11. Gasc J.-P. (ed.) (1997). – Atlas of amphibians and reptiles in Europe. Societas Europaea herpetologica, Muséum National d'Histoire Naturelle, Paris, 495 pp.

12. Grosselet O., Thirion J.-M., Grillet P. & Fouquet A. (2006). – Le xénope lisse, une nouvelle espèce invasive en France. *Le Courrier de la Nature*, **225**, 22-27.

13. Haffner P. (1997). – Bilan des introductions récentes d'amphibiens et de reptiles dans les milieux aquatiques continentaux de France métropolitaine. *Bull. fr. Pêche Piscicult.*, **344/345**, 155-163.

14. Marris E. (2008). – Bagged and boxed: it's a frog's life. *Nature*, **452**, 394-395.

15. Neveu A. (1997). – L'introduction d'espèces allochtones de grenouilles vertes en France, deux problèmes différents: celui de *R. catesbeiana* et celui des taxons non présents du complexe *esculenta*. *Bull. fr. Pêche Piscicult.*, **344/345**, 165-171.

16. Régnier C., Fontaine B. & Bouchet P. (2009). – Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conserv. Biol.*, **23** (5), 1214-1221.

17. Servan J. & Arvy C. (1997). – Introduction de la tortue de Floride *Trachemys scripta* en France. Un nouveau compétiteur pour les espèces de tortues d'eau douce européennes. *Bull. fr. Pêche Piscicult.*, **344/345**, 173-177.

18. Sodhi N.S., Bickford D., Diesmos A.C., Lee T.M., Koh L.P., Brook B.W., Sekercioglu H. & Bradshaw C.J.A. (2008). – Measuring the meltdown: drivers of global amphibian extinction and decline. *PLoS ONE*, **3** (2), e1636, 8 pp.

19. Stuart S.N., Chanson J.S., Cox N.A., Young B.E., Rodrigues A.S.L., Fischman D.L. & Waller R.W. (2004). – Status and trends of amphibian declines and extinctions worldwide. *Science*, **306**, 1783-1786.

20. Swan G. (2006). – Frogs of Australia. New Holland Publishers, Sydney, 96 pp.

21. Williamson M. (1996). – Biological invasions. Chapman & Hall, London, 244 pp.


# Internet sites


Amphibian Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature: www.amphibians.org/ASG/Publications.html

International Society for the Study and Conservation of Amphibians: www2.mnhn.fr/alytes/

Reptile specialist groups of the Species Survival Commission of the International Union for Conservation of Nature: www.iucn.org/about/work/programmes/species/about_ssc/specialist_groups/