The notorious cane toad. Image: A Turner and SJ Davies

John Measey and **Sarah Davies** discuss the emerging problems associated with invasive amphibians.

Hopping invaders

Many of us share our environment with a number of wild animals, and among the vertebrates, the amphibians (Class: Amphibia) may be the most numerous. In South Africa, amphibians are only represented by frogs (Order: Anura), but worldwide there are two other groups, the tailed salamanders (Order: Caudata), and the limbless caecilians (Order: Gymnophiona). Together, there are more than 7 300 species, with the frogs making up 88%. Considering the total number of species, only a handful of these have been moved outside of their native ranges (147 frogs; 37 salamanders, 2.5%), and an even smaller number (1.4%) are thought to have successfully established invasive populations. These invasions have not been equally distributed across the world, with Australia, Europe, USA and many of the Caribbean islands receiving far more introductions than elsewhere. But what's the fuss about? How could invasive amphibians possibly become a problem, and why would people want to move them in the first place?

Moving amphibians

The pathways which have led to amphibian introductions include unintentional movement, similar to many of the other invasive plants and animals. Have you ever bought a pot plant, only to find when you get home that there's a frog in it? Or

Distorted Earth. This image shows a 'cartogram' where the size of each country is proportional to the number of known amphibian invasions it has received. Note how most of Africa has shrunk to almost nothing, while Europe, USA and many of the Caribbean islands are larger than they would normally appear. Image: John Measey

pulled a bunch of bananas apart to find a frog sheltering inside? Some frogs (especially the toads: Family Bufonidae) regularly inhabit areas that we light up at night, feeding on the insects that are attracted to our lights. Before day breaks, they'll be looking for places to hide from the sun and readily enter into dark boxes. If such boxes happen to be at a port, they could be picked up, placed on boats and shipped around the world. When the containers are opened up again, the animals can find themselves on another continent, and if it isn't too cold (and if they arrived with a mate) you can imagine how it is possible for them to start an invasive population. But perhaps the most unexpected pathways of amphibian invasions are the deliberate movement and introductions of frogs for a whole host of reasons.

The cane toad (*Rhinella marina*) is probably the best-known invasive amphibian in the world, and certainly the most studied. Originating in Central and South America, cane toads have been introduced to at least 90 different sugarcane growing areas in the Caribbean, Australia and Pacific since the 1930s. It was thought that the toads would control a number of beetle pests that were causing problems for sugarcane growers. The rest, as they say, is history. With so much help from those who introduced them, cane toads have quickly established invasive populations in many of the sites in which they've been introduced. The largest area invaded is Australia, where the toads are still spreading across the world's largest island. The cane toad isn't alone in its attempted use as a cane-beetle predator. The islands of Reunion and Mauritius (east of Madagascar) imported guttural toads (*Amietophrynus gutturalis*, which also occur naturally in South Africa) which have since become a real problem all over these islands. One of the hazards that the toads bring is their parotid glands (these contain bufotoxins that the toads excrete whenever they are threatened), which poison any potential predators and have caused serious declines for anything that wants to eat them.

You may well have heard of frogs legs as being a delicacy of the French, but there are plenty of people who want to eat them, enough for there to be a global market in frogs legs. Clearly, it makes sense to grow your meat as locally as possible, so in the 1990s a trend started for farming frogs, and the species selected for this enterprise had many of the attributes we associate with invasive species: they had a cosmopolitan diet, grew fast, and were able to live in many climates. Although not the only species to be part of this aquaculture trade, the American bullfrog (*Lithobates catesbeiana*) has become invasive in 31 countries. Science has also had a role to play in the pathways of invasive frog introductions, and the subject of this story involves a frog which should be very familiar to many readers: the platanna or African clawed frog (*Xenopus laevis*: see Box 1). Interestingly, these animals became so easy to breed and keep in captivity that they became extremely popular in the pet trade, and this has resulted in more introductions and the establishment of invasive populations.

The American bullfrog. Image: Wilkimedia commons

Invasive impacts

You might think that we know enough about the problems of invasive amphibians that their movement would be prohibited, but this is not the case. For example, within the USA, between 2001 and 2009, 20 million American bullfrogs and 1.25 million platannas were traded. During the same period, the USA exported 12 000 and 120 000 of the same two species, and the trade in amphibians is growing as the demand for rare or unusual pets increases. As the trade grows the numbers of amphibians that are likely to escape increases and so the number of invasive populations increases. But what impacts do these invasive frogs make when they establish a new population?

Invasive frogs can affect the environment into which they are introduced in many ways. Frogs are prodigious predators, as anyone who has tried to keep a frog in captivity will know. Even a very small frog can happily eat ten or fifteen insects per day! Therefore, when there are many frogs in an area there can be a major impact on insect populations. Frogs also eat other frogs, and this could result in native frogs becoming rarer or even going extinct, particularly if the invading species is large, like the American bullfrog.

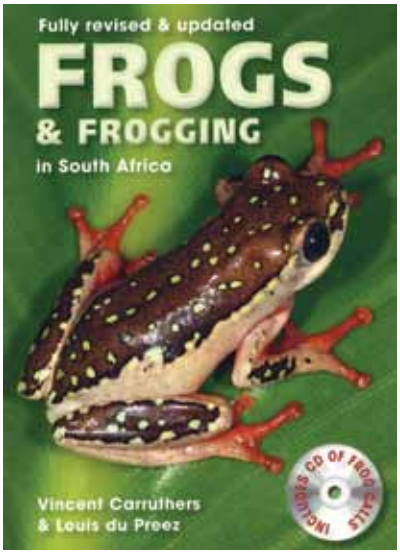
Opportunity cost

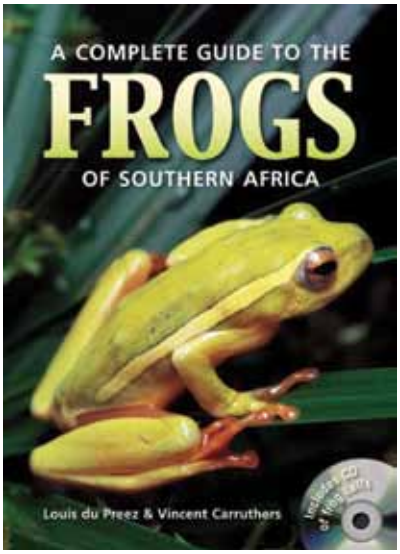
One interesting impact of frog extinctions is called 'opportunity cost'. This means that if a species is already extinct, or very rare and difficult to find, we will not be able to find out whether there are possible economic and social uses of these animals. Thus, humans will lose an opportunity they would have had if the species had survived or been protected. Some frogs have already given scientists

natural compounds or templates for making synthetic chemicals that could help in treating cancer and other diseases. This is why it is important to support nature conservation efforts in your area, and be aware of the global threats to frogs, such as the loss of wetlands and climate change.

When animals or plants enter a new environment they can transport disease-causing organisms with them, such as bacteria, viruses or fungi. This may be what happened when the platanna was introduced to North America. Native frogs may have been infected by a fungus carried by the introduced frogs, causing them to become sick and die in large numbers.

Some introduced frogs become extremely abundant, and this can affect other aspects of the ecology in the area where they are introduced. For example, coqui frogs (*Eleutherodactylus coqui*) are very abundant in forests on Puerto Rico island and can consume up to 115 000 insects per night. The waste from these frogs, as well as their decomposing bodies when they die, provides nutrients, such as nitrogen and carbon, for plants and





Two useful books on frogs.

decomposer organisms. Researchers found that if the frogs were kept out of an area, the rate of nutrient cycling in the forest slowed down, and some plants grew more slowly.

What can you do?

If you're interested in finding out more about South Africa's frogs and those from other countries, there are many excellent resources you can use to learn more. Field guides are available in many libraries and bookshops (see the book covers). You can get to know the frogs in your area by looking in the vegetation around ponds and dams, especially during summer. Even if you cannot see them, you may be able to hear them calling. The field guides shown are great because they include CDs with the calls of each species, so that you can become familiar with them and identify them without even seeing them. Many people think that the frog sounds they hear at night are made by insects or birds, when many of them are the mating calls of nocturnal frogs. South Africa has 125 species of frogs and it's possible to become familiar with most or all of their calls.

If you have a water body near your home, you can monitor the frog

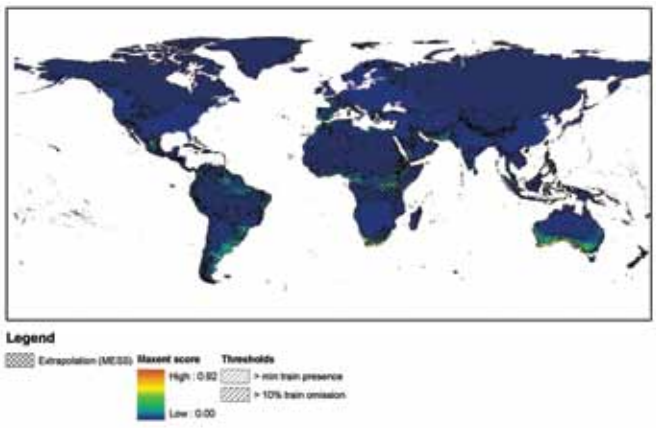
Box 1: Common platanna

The platanna or African clawed frog (*Xenopus laevis*) first became of interest to the wider scientific community in the 1930s. Endocrinologists found that hormones present in the urine of pregnant women stimulated female platannas to lay eggs. As platannas bred throughout the year and were easily maintained in the laboratory, this was found to be a suitable animal for pregnancy tests. And so began a massive trade in live animals from South Africa to pregnancy clinics around the globe.

Once again, the properties that made this species useful in the laboratory (large size (producing lots of eggs), hardy (to many environments), resistant to disease) also made the species ideal for invasions so that when colonies escaped, or were released, they quickly started invasive populations. Being primarily aquatic, the platannas have been shown to have a negative effect on local amphibians, eating their eggs and tadpoles as well as adults. The impact on freshwater invertebrates is not well known, but it has been suggested that this species is capable of changing the ecology of the ponds it invades.

Some of the first invasive populations were in the USA and UK, and date back to the period when this species was regularly used in pregnancy testing. However, invasions have continued right up to the present, and invasive populations of this species are now found on four continents. Worse, this species is known to harbour a fungal pathogen (*Bd*), known to have grave adverse effects on many other amphibian species. Whether or not this pathogen originally came from South Africa, the invasive populations now act as a reservoir.

*A global invader: the African clawed frog or platanna (*Xenopus laevis*).*
Image: John Measey



Global distribution model. Scientists have projected the climate of the platanna to see where in the world it may spread. Note how suitable climates cover much of Australia, Europe, Mexico and South America.

Groups of amphibians	Numbers of frogs (Anura)	Numbers of salamanders (Caudata)	Numbers of caecilians (Gymnophiona)
Number of species which have been introduced worldwide	125	37	0
Number of species which have become established outside their natural range	85	19	0
Number of species indigenous to South Africa#	119	0	0
South African endemic species	66	0	0
Domestic exotics*	3	0	0
Invasive alien species from outside SA	0	0	0
South African species that are invasive elsewhere in the world	2	0	0

New species are still being described in South Africa, so this number is rising.
*Species which are native to South Africa, but have been moved by humans outside of their natural range.

A table showing the numbers of invasive amphibians globally and in South Africa.

populations there each summer, and try to identify all the species that are calling there. The story of a frog that likes to breed in farm dams and garden ponds is told in Box 2. You will find that frogs call most when the weather is warm and moist and not too windy, and most frogs are nocturnal. However, in the Western Cape and Northern Cape many species breed in winter instead of summer, and these species are adapted to cold weather.

Note: you need a permit to keep a South African frog as a pet.

iSpot is a website devoted to recording people's encounters with nature (http://www.ispotnature.org/communities/southern-africa). Once you have registered on iSpot, you can send your photos of animals you see and experts can help you identify them. You can also find out what observations others have made and whether your observation is new or unusual. **Q**

John Measey has been working with amphibians for more than 20 years and is currently the IUCN's chair of the Amphibian Specialist Group in southern Africa. John has worked on invasions of the platanna on three continents, and his students now study local invasions in South Africa. He is a senior researcher at the C•I•B hub at Stellenbosch University.

Sarah Davies works with the C•I•B team at Stellenbosch University. She completed her PhD in 2014 on the invasion of the painted reed frog in the Western Cape of South Africa, and thinks that amphibians are the coolest vertebrates in the world.

Box 2: The painted reed frog

The South African Frog Atlas (http://adu.org.za/frog_atlas.php) was compiled by many herpetologists and volunteers going out and listening for frogs around their homes, and in more remote areas. Eighty seven percent of the quarter degree squares (QDS) in South Africa were visited and the frogs recorded there. (A QDS is the area covered by a 1:50 000 topographical map, so you can imagine that this involved a lot of field work.) During the Frog Atlas process, when they were comparing the field results with specimens that were kept in museums, scientists noticed that some species were becoming more widespread than they had been in the past. For example, the painted reed frog (*Hyperolius marmoratus*), a species from the eastern parts of the country, was found living in the Stellenbosch area, and scientists at CapeNature and Stellenbosch University began to study its spread. When Sarah Davies was conducting research for her PhD, she noticed that most of the painted reed frogs in the Western Cape live in dams and ponds that have been built by farmers and land-owners to provide water for irrigation.

A dam in which painted reed frogs were found. Image: AA Turner

A painted reed frog. Image: AA Turner

Frogs can move between these water bodies by hopping, if the distances are small, or via vehicles, goods or plants that are being transported across larger distances. If drivers don't check their vehicles and cargo, there could be a couple of small frogs sitting on or in their vehicle and they may be taken to another pond where they could mate and lay eggs. After two years, these could have developed into a whole new generation of adult frogs, and a few individuals could, in turn, spread to a neighbouring pond. In this way, painted reed frogs have spread to over 3 000 km^2 of the Western Cape Province. This is a very rapid rate of spread if you consider that species usually spread very slowly – for example many species went extinct at the end of the last ice age because they could not track the climate changes fast enough. In this case of human-mediated biological invasion, only fifteen years were needed for the frog to extend its range westwards by over 600 km.