impact

Figure 1 A cane t
(*Rhinella* [previous
marina) with large
gland swellings be
each eye

Cane toads in Australia

Biological control that backfired

The Australian continent is plagued by imported invasive pests. None is more despised than the cane toad. This large, toxic toad threatens several native Australian species and is spreading rapi Biologist Teresa Audesirk explains how this problem arose and the efforts being made to solve it

Cane toads are large amphibians. They average 10–15 cm in length but sometimes reach up to 25 cm. They have dry, warty skin, mottled in shades of grey and brown. They are native to the Americas, ranging from southern Texas to the tropics of South America. Adults are terrestrial, returning to water only to lay eggs. They become sexually mature at about 18 months, and live for 5–10 years. They can reproduce in nearly any freshwater habitat, from puddles and ponds to lakes and reservoirs.

Key words

Biological control
Amphibian
Introduced species
Invasive species
Selection pressure
Natural selection

The common name 'cane toad' was applied after their introduction to tropical islands to control populations of sugarcane beetles. The toad is now well established in many countries, but has its impact been as severe as in Australia. M 80 years after its introduction, the cane toad spreading rapidly.

Cane toads produce a deadly poison called **bu** The toxin is secreted by glands in the skin and als **parotid glands**, which are visible as large swelling toad's back behind each eye (see Figure 1). A th toad secretes, and sometimes even squirts, this whit substance at its attacker. Many native Australian p — and pet dogs — are poisoned and die when they to consume cane toads. Substances in the toxic secre cause hallucinations, so people seeking a 'high' so

Terms explained

Bufotoxin A toxin produced in the skin of many species of toads, and some other amphibians, which deters predators. The primary toxic effects are on the heart and nervous system.

Cane beetles Beetles that feed on sugar cane. The Australian species' adults eat sugarcane leaves and the larvae eat the roots.

Parotid gland A gland located behind the eyes of certain toads and other amphibians that secretes bufotoxin, which poisons potential predators. (The largest human salivary glands are also called parotid glands.)

milk the toads or lick them to acquire the toxin (a practice now outlawed in Australia).

How did cane toads end up in Australia?

In the 1930s, sugarcane farmers in the state of Queensland were suffering enormous crop losses to **cane beetles**. Extensive research on ways to limit cane beetle infestations had yielded no effective solutions. Importing cane toads, which were believed to have helped control these pests in Puerto Rico and Hawaii, seemed to be the answer. Organisms imported to control a pest — called biological controls — can reduce the need to use toxic pesticides, but there is always a risk that they will create problems of their own.

The first batch of about 100 toads was imported from Hawaii in 1935. They were bred in captivity, producing 2400 toads for release in under 2 months. The following year, under pressure from the sugarcane industry, thousands more cane toads were liberated into sugarcane fields in Queensland. Nobody knows how many now inhabit Australia, but some researchers estimate as many as 2 billion.

Do cane toads control Australian cane beetles?

There is no evidence that cane toads have helped to control cane beetles in Australia. The success of cane toads on small islands was probably exaggerated, and they are now also a pest in Hawaii. The Australian continent offers unparalled opportunities for these warty invaders. Spreading far beyond sugarcane fields, they eat almost anything they can fit into their mouths. They feed mostly on insects, but also eat dog food, small lizards, snakes, birds, rodents and amphibians — including each other. Their tadpoles eat their own and other amphibian eggs, acquiring food and reducing competition. When ponds shrink during the dry season, juvenile cane toads eat smaller juveniles.

How do introduced species become invasive?

Australia has many introduced species. The dung beetle, which was introduced to break down accumulating cow dung, has been a great success. But others have become invasive. Invasive species compete with, or prey on, indigenous (native) species, disrupting the natural balance of ecosystems. Because they did not evolve in their new environment, invasive species have few predators, and native prey have not evolved defences against them. Invasive species generally reproduce rapidly and tolerate a wide range of environmental conditions. Ironically, the cane toad preys heavily on the introduced but beneficial dung beetle.

Cane toads can reproduce twice a year. Females lay up to 35000 eggs each time. Even though only about 0.5% of these reach reproductive age, the survivors more than replace their parents, causing a population explosion. The expanding population can colonise new territory because the toad is very adaptable. Although native to tropical and semi-tropical regions, it can withstand drought and cold, tolerating a loss of 50% of its body water and surviving temperatures from 5°C to 40°C. Its habitats include swamps, grasslands, open forests, farmlands and suburban neighbourhoods.

As cane toads invade new areas, many native predators that attempt to eat them are poisoned. Large declines in the numbers of black snakes, goannas (large monitor lizards), northern quolls (marsupial mammals), and freshwater crocodiles have been reported soon after toad invasion.

Responses to the invaders

Fortunately, after decades of coexistence, some predators, including goannas in Queensland, have adapted to avoid the toads, and goanna numbers are beginning to recover. Goannas that attempt to eat small cane toads can survive and learn from the experience. Researchers plan to release small cane toads in key wildlife preserves before large toads invade, hopefully protecting local goanna populations.

Northern quolls also learn to avoid the toads. These marsupial predators are already endangered by habitat loss and feral cats, so poisoning by cane

Dung beetles — a successful introduction to Australia

Red-bellied black snakes (top) and goannas (bottom) are prone to poisoning by cane toads

toads adds a new threat to their survival. Toads are now spreading towards one of the last quoll strongholds (called 'the Kimberley') in northwestern Australia. Scientists are attempting to toad-proof the Kimberley's quolls by feeding them a nauseating ingredient added to ground-up cane toad legs. Quolls (like many other animals) readily learn to avoid foods that make them sick. Quolls released into the wild after being fed this mixture in the laboratory were better at avoiding cane toads than were quolls in a control group. So now this nausea-inducing mix is being packaged in sausage-casings and dropped from helicopters into the Kimberley, with the aim of duplicating the laboratory results in the wild.

Both predators and cane toads are evolving rapidly

Cane toads act as powerful agents of natural selection on their predators. Individuals carrying mutations that help them instinctively avoid the toads or withstand cane toad poison are spared. Over many decades, descendants of predators that carry these survival traits become more common in regions with toads, allowing predator numbers to recover.

Laboratory studies suggest that the presence of cane toads is changing red-bellied black snake behaviour. These snakes often attack cane toads, which resemble their normal diet of native frogs. In a laboratory study, 50% of snakes collected from areas never invaded by cane toads attempted to eat the toads. In contrast, none of the snakes from a region that had been occupied by toads for 40–60 years tried to eat them (see Figure 2). All of these black snakes ate native frogs.

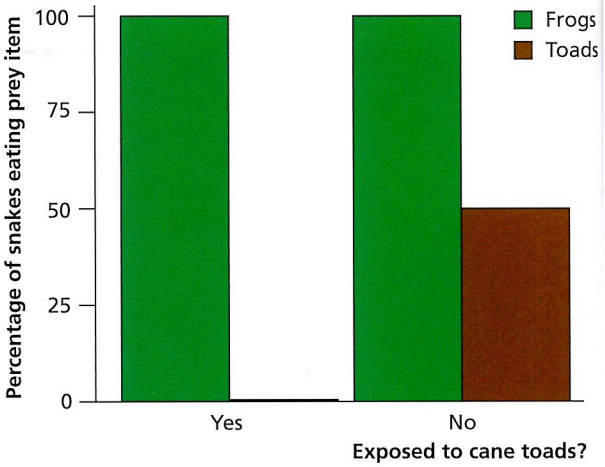

Figure 2 The percentage of red-bellied black snakes from toad-exposed and non-exposed populations that ate frogs ar toads. Each group of snakes consisted of 12 individuals

Black snakes are unable to learn to avoid cane toads i the laboratory, suggesting that the changed behaviour wild snakes is unlikely to result from learning. This provid evidence that, in the wild, cane toads have exerted selectic pressure, favouring snakes that instinctively avoid toads.

Cane toads themselves are also evolving. Toads in th front lines of the invasion have different characteristics fro those in areas colonised decades ago. They have longer leg grow more quickly, are more active, move in a straight path, and have greater endurance (which allows them spend more time hopping each day). As they move togethe toads at the invasion front breed with one another, passi on these traits. Natural variation will make some of th offspring surpass their parents. As these progeny breed wi one another, they produce still more athletic toads. Toa leading the invasion of one new territory moved about te times further each day than those that were not dispersin

The invasion has been accelerating

As toads evolve to disperse more rapidly, the rate at whi they invade new territory has increased. They are nc spreading over five times faster than during the first fe decades after their introduction (see Figure 3). In the 196(toads spread by about 10 km per year — now that figure up to 60 km per year.

From Queensland, where they were introduced, cane toa have spread across northern and northeastern Australi and researchers predict that they will continue to migra westward and into southern coastal regions (see Figure 4)

Can the invasion be controlled?

Residents have become so frustrated with cane toads th they have resorted to killing them with baseball bats a hammers, though more humane methods are encourage Meanwhile, researchers are seeking ways of reducing to numbers. One approach is to use the cane toad toxin. Th acts as an attractant to the cannibalistic toad tadpol which then eat the eggs laid by females other than th own mothers. An extremely low concentration of the tox

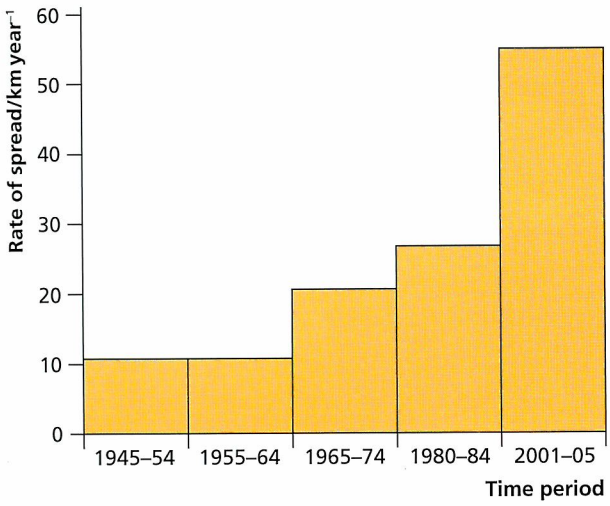

Figure 3 Cane toads are spreading through Australia at an increasing rate

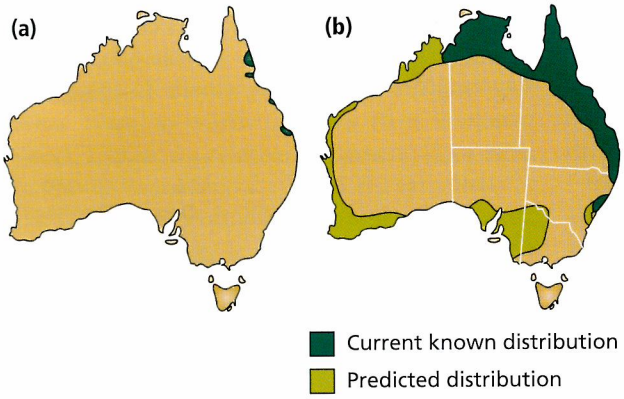

Figure 4 (a) Distribution of cane toads in Australia in 1940; **(b)** known and predicted distribution in 2016. The prediction is based on regions with suitable habitat

lures cane toad tadpoles, with no effect on other aquatic wildlife. Traps equipped with a narrow funnel-like opening and seeded with this bait have caught more than 50000 tadpoles at one site in 2 weeks, significantly reducing the local population. Both the trap design and the bait chemical are now being refined for mass commercial production.

The future: coexistence

Thanks to their ill-fated introduction of 1935, cane toads are now a permanent part of Australia's fauna. They affect Australian wildlife and ecosystems both directly and indirectly. Directly, they have caused a decline in native species of lizards and mammals. Indirectly, the loss of these predators has allowed their natural prey to increase in numbers, with ecosystem-wide impacts. People may succeed in slowing the toads' advance and excluding them from specific areas but, ultimately, only extremes of temperature and aridity will limit their distribution. The wildlife of Australia will be forced to reach a new equilibrium with the cane toad.

Preparing to release a quoll back into the wild after laboratory training

Topics for discussion

- What studies should have been performed before cane toads were released into Queensland cane fields?
- Why would Australian farmers have felt a need to introduce dung beetles to break down cow dung? (Hint: are cows native to Australia?) What is the likely impact of cane toads feeding on these dung beetles? Use this as a starting point to discuss the far-reaching impacts of human-introduced species, from livestock to accidentally introduced species to attempted biological controls.
- Consider ways in which the ecosystem could be disrupted when cane toads greatly reduce populations of predators such as northern quolls and goannas.

Further reading

The biology, distribution and attempts to control the cane toad in Australia: **https://tinyurl.com/ydg2pww7** and **https://tinyurl.com/z5uv7u2**

Identifying features of cane toads: **https://tinyurl.com/mvyx4z3**

University researchers have produced a toad-trapping device and begun to commercialise it: **https://tinyurl.com/mymry8u**

More about research on cane toads: **www.canetoadsinoz.com**

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