

THE TOADS are coming!

Cane toads are infamous for wreaking havoc on Australian ecosystems. But, as Peter Aldhous discovers, we're only now about to learn whether their fearsome reputation is deserved.

Darwin is bracing itself for an invasion. *Bufo marinus*, otherwise known as the cane toad, has been advancing across the Australian landscape for decades. Ravenous, poisonous and an explosive breeder, it has acquired a reputation for wiping out this country's unique wildlife. Now the front line is just a few tens of kilometres from the capital of the Northern Territory; the first invaders are expected to hit the city's limits before the wet season ends next May.

This prospect horrifies Darwin's residents. They have visions of their pets being poisoned by the toads' potent toxins, while their swimming pools fill with the loathsome beasts. But as the cane toads approach Darwin, scientists are also being presented with their best opportunity to investigate the ecological impact of the amphibians. Despite the animals' infamy, this remains largely a matter of conjecture. "That's the whole thing with the toads," says Tony Griffiths, an ecologist at the Key Centre for Tropical Wildlife Management, based at the city's Charles Darwin University. "Most of it is anecdotal. There has been very little scientific evidence."

Until now, that is. With Griffiths and his colleagues David Bowman and Barry Brook, I'm surveying the front line from a helicopter, swooping over the huge flood plain of the Adelaide River, just outside Darwin. The landscape here is ideal territory for the toads, which hail from the wetlands of South America. "This is the closest thing to the Amazon flood plains that you are going to get in Australia," says Brook.

Cranes, geese and buffalo scatter beneath us, as we pick out the tracks of crocodiles in the mud. For decades, ecologists have flown over, walked through and scrutinized this plain and its neighbouring habitats. When the toads arrive — which they could do within weeks — they will be closely watched, providing the most detailed study yet of an invasion by a vertebrate on this scale. It's quite possible, says Bowman, that this will reveal that the toads' reputation for ecological vandalism has been exaggerated.

Cane toads were first introduced into



Under attack: Darwin (above) is about to be hit by a hoard of voracious cane toads (top left). Already, the northern quoll (left) seems to be falling victim to the amphibians' poisonous charms.

Queensland in 1935, to control beetles that were ravaging the sugar harvest. But the toads found other invertebrates more to their taste, and have since competed vigorously with native insectivores. They have also defeated most of their predators; the bulging poison glands behind their eyes mean that a first encounter with a cane toad is often the last.

But it's impossible to blame the toads definitively for the decline of any particular species. In the first few decades after the animals arrived, biologists were little concerned about the dangers they posed, and so didn't collect any data. More recently, the toads have been advancing to the northwest across

the remote Gulf of Carpentaria, where few ecologists venture. In fact, the toads attracted little scientific attention until 2001, when they showed up in Kakadu National Park.

This area of pristine wetlands and savannah forest, which enjoys World Heritage status, hosts some animals that are particularly sensitive to changes in the environment — including the northern quoll (*Dasyurus hallucatus*). "If ever there was a species highly adapted for extinction, it's the quoll," says Rod Kennett, Kakadu's project officer for ecology and natural-resource management. Seldom seen, the northern quoll is a rabbit-sized marsupial carnivore that will try to eat anything it





On the front line: (from left) Tony Griffiths, Barry Brook and David Bowman hope to learn more about cane toads' ecological effects as the animals spread across northern Australia (below).

There she is, bounding back and forth in the cage, large-eyed and inquisitive. Ansell manoeuvres her into a cloth bag, and she calms down. He identifies her from a microchip injected beneath her skin the first time she was trapped, and takes a series of measurements — weight, head length and so on. Her teats reveal that she is nursing about half a dozen young. Then she is released to scamper off into the night.

By the time we finish, around 2.30 a.m., we have caught two more females. The next night, we trap the same three animals — indicating that they represent the majority of the local population. The prognosis isn't good. This time last year, we might have captured 20 quolls each night, Ansell says.

At Oakwood's other field site, to the southwest, the news is even grimmer. There, the quolls disappeared about 18 months ago. Several radio-collared animals were found dead with reddened gums — a tell-tale sign of cane-toad poisoning.

Kennett has little doubt that Kakadu's quolls are finished, so he is now concentrating the park's research funding on Griffiths' work on another vulnerable predator, the monitor lizard *Varanus panoptes*. These lizards have declined in number since the toads arrived in Kakadu. But there is at least some hope that populations might stabilize and bounce back — so Kennett wants to keep watch for future developments.

More signs of the toads' damaging effects come from a series of automated 'toad poles' in Kakadu — listening devices that pick up the calls of cane toads and native amphib-

ians. A team led by Gordon Grigg of the University of Queensland in Brisbane has preliminary data from these devices suggesting that the toads' arrival coincides with decline of native frogs.

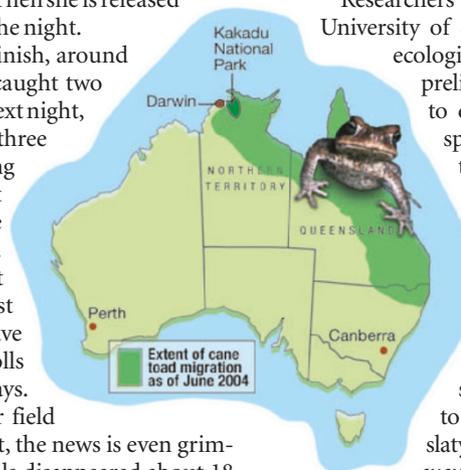
This all sounds like damning evidence, but the big picture is likely to be more complicated. Even for the quolls, the toads may be just part of the story. Together with most of northern Australia's small mammals, quolls are in decline even in areas that haven't been invaded by cane toads. This is probably because of changes in fire management. For thousands of years, Australia's Aboriginal people burned the landscape frequently, but each fire was small, so any one patch would burn only once every few years. This created a rich mosaic of habitats, boosting biodiversity. Today's ranchers, in contrast, burn large areas each dry season.

Last suppers

These and other ecological pressures on the Darwin area (see 'On the wild frontier', overleaf) will all play a role in how the toads affect the ecosystems in and around the city. The extent to which an individual species is threatened by the toads will also depend on nuances of its ecology and behaviour. Some species of monitor lizard spend much of their time in water, for instance, which may limit their contact with the toads.

Researchers led by Rick Shine of the University of Sydney, a leading snake ecologist, are conducting some preliminary lab experiments to determine which of the species they study are likely to be most at risk. Of the non-venomous species, water pythons (*Liasis fuscus*) are probably safe, because they feed almost exclusively on rodents. Keelbacks (*Tropidonophis mairii*) seem reasonably resistant to the toad toxins, but slaty-grey snakes (*Stegonotus cucullatus*) are less so. The area's venomous snakes, meanwhile, have little resistance at all. "They are really going to be in trouble," predicts Greg Brown, a Canadian postdoc in Shine's team.

For such species, the hope is that they will cling on long enough for natural selection to lend a helping hand. Shine's graduate student Ben Phillips has examined museum specimens of snakes from Queensland, finding that vulnerable species may adapt over the generations to evolve smaller mouths and larger body sizes, making them less likely to eat a toad big enough to poison them (B. L. Phillips and R. Shine *Proc. Natl Acad. Sci. USA* **101**, 17150–17155; 2004). But the acid test will be what happens when the toads arrive at the team's main field site — an



can capture. This, combined with its unusual breeding habits, makes it especially vulnerable to the sudden appearance of an army of toxic creatures. The males all die each breeding season, exhausted by frenetic mating, and relatively few adult females make it from one year to the next, even in good times. Take out a small number of nursing mothers towards the end of the breeding season, and a local population can crash precipitously.

On the brink

So Kennett asked Meri Oakwood, who runs the consultancy Envirotek, based in Nana Glen, New South Wales, to keep an eye on the quolls. Unsurprisingly, she has found that they are not faring well.

Two nights spent at the northeastern boundary of Kakadu in mid-October brings this point home. Visiting the park with Shaun Ansell, a student at Charles Darwin University who works on Oakwood's project, I help to lay 50 wire-cage traps around a series of rocky outcrops, and bait them at sunset with a mixture of peanut butter, oats and vegetable oil — irresistible to small mammals. By 12.30 a.m., we've examined half the traps, finding nothing but rock wallabies and rodents. Then, Ansell shouts: "Quoll!"

artificial wetland created by a barrage known as Fogg Dam.

Countless nights walking the road along this dam have given Brown a supernatural eye for spotting snakes. I tag along with him for an evening's snake survey, and within a few minutes, his flashlight picks out a water python slithering through the undergrowth.

Brown later repeats the trick from the front seat of his four-wheel drive. As we negotiate the rough track across the nearby Harrison Dam, he spots one of each of his two main study species, the keelback and the slaty-grey. By the end of the evening, we've recorded a total of seven other water pythons. Not a bad night, says Brown. "But come back in a year, when the toads are everywhere, and who knows what you might or might not see."

Toad haul

Another project in the same area will examine the toads' appetite for invertebrates. One of Shine's undergraduate students, Matt Greenlees, has built a series of small metal enclosures in which he plans to put toads, to see how much damage they inflict on populations of insects and other invertebrates. Once the toads have colonized the Fogg Dam area, he will clear the enclosures and maintain them as toad-free habitats.

Out in the field at Fogg Dam with Brown, people driving by stop to ask what we're doing — and then want to know whether the toads can be stopped. The locals' concern is laudable, but has itself brought some adverse consequences for native wildlife. On a recent radio show, one caller gleefully described how she had driven back and forth over a mass of cane toads. But the toads had yet to hit her locality. She had probably squashed a bunch of superficially similar native marbled frogs (*Limnodynastes convexisculus*).

So can anything be done? At the inaugural meeting of the National Cane Toad Task Force, held in Darwin in late October, there were few answers. Discussions about strategies for trapping toads to keep their numbers down in key habitats were plagued by the phrase "preliminary data". With so much in doubt, it's going to be difficult for the task force to devise a plan.

Those who have been calling for officials to address the issue for years can't conceal their fury. "Nobody lifted a bloody finger," complains Grahame Webb, who runs a wildlife research and education centre outside Darwin, and chairs the World Conservation Union's Crocodile Specialist Group.

Now a rearguard action is under way. The Northern Territory government, national-park officials and Aboriginal representatives are moving small populations of quolls to toad-free islands off the coast. If researchers find a way to wipe out the toads, the predators could then be reintroduced to the mainland.

But that's a distant prospect. Researchers with the CSIRO, Australia's national research

On the wild frontier

Today, Darwin is cosmopolitan, laid back, and a Mecca for backpackers. But not so long ago, it was a rough-and-ready frontier town — where people lived hard, drank hard and settled arguments with their fists.

Viewed from the air, it's clear that this is still a frontier town in another sense. Darwin is a small urban island in the midst of a largely untouched tropical wilderness. There are mangroves, flood plains and expanses of savannah forest that stretch as far as the eye can see. Patches of denser rainforest break up the scene, growing where groundwater lies closer to the surface.

So far, the city has done little to spoil this landscape. Indeed, its suburbs and satellite towns actually support a higher density of small mammals than the surrounding wilderness — probably because their spread-out development has created a patchwork of habitats (right) that mimics the beneficial pattern formerly created by ancient aboriginal burning practices.

But accelerating agricultural and industrial development could soon disturb this idyllic scene. Savannah forest is being cleared to grow cotton and other thirsty crops, which drain the groundwater. And a gas liquefaction plant is being built near the city's harbour. It is all part of the Australian government's policy of investing in its northernmost outpost.

Although the cane toad may be the best known threat to the habitats around Darwin, this burgeoning development could in the long run prove much more significant. "We're looking at an entire ecosystem being transformed under our feet," says David Bowman, who directs the Key Centre for Tropical Wildlife Management

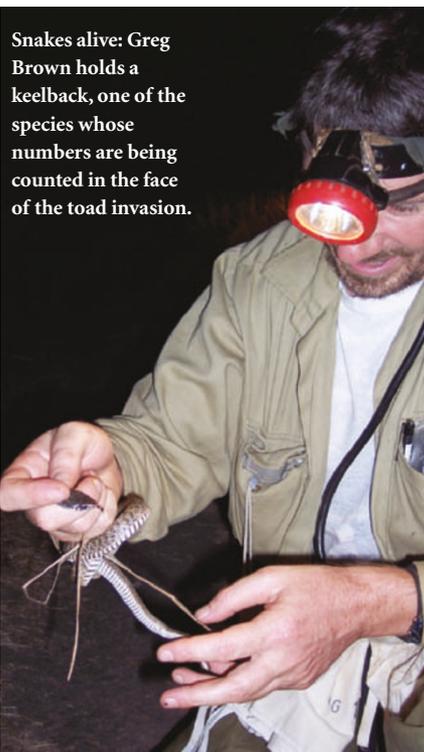


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at the city's Charles Darwin University. "In ten years, you won't be able to recognize the joint."

The good news is that, unlike other tropical landscapes facing similar problems, this wilderness is in a rich country with a habit of supporting ecologists keen on studying habitat change. Bowman and his colleagues are now applying for a five-year, A\$24-million (US\$19-million) grant to determine how various development pressures are affecting the region's landscapes and biodiversity. They hope to provide information that could allow Darwin's economy to grow in an environmentally sustainable way.

Whether that information will be used or not remains to be seen. First, says Bowman, developers and conservationists will have to step down from their diametrically opposed positions, and start listening to each other.



Snakes alive: Greg Brown holds a keelback, one of the species whose numbers are being counted in the face of the toad invasion.

agency, are trying to identify cane-toad-specific genes that control the development of tadpoles into toadlets. They then hope to engineer a ranavirus, which infects amphibians, to specifically disrupt these genes.

It might just be possible to tackle cane toads this way without threatening native amphibians: Australia has no other members of the family Bufonidae, to which the cane toad belongs. But there are bufonids in neighbouring southeast Asian countries. So any attempt to release such a virus could spark an international outcry — even if the Australian public was prepared to countenance the idea.

Bowman believes that the best hope lies with ecology, rather than genetic engineering. Northern Australia will have to learn to live with the toads, he argues. Ecological studies may reveal subtle ways of manipulating native habitats, through controlled burning perhaps, to minimize the damage they cause. Expecting a "cheap fix" of biological control to come to the rescue, Bowman suggests, is wishful thinking. After all, it was a misguided attempt at biological control that created the problem in the first place. ■

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