by David Pearson, Jonathan Webb, Errol Kruger and Rick Shine

THE MARCH OF THE CANE TOAD

Since their introduction to Australia more than 70 years ago, cane toads have been on the march, relentlessly expanding their distribution across the north of the continent. They have spread out through the wet tropics of Queensland, trooped south into New South Wales and hopped west to the Northern Territory. The first toads will soon reach Western Australia. What work is being done to ensure we are as prepared as possible for their inevitable arrival?

Cane toads were deliberately introduced as a biocontrol agent for insects affecting sugar cane crops in Queensland. What was poor Reg Mungomery thinking when he shipped about 100 toads from Hawaii? He has been pilloried as an ecological villain, but, at that time, cane beetles were devastating sugar cane crops in a number of countries and agricultural agencies were desperate to find a way to control this pest. The cane toad (*Chaunus marinus*, formerly *Bufo marinus*) was seen as a saviour, a rather ugly knight in warty skin but battle hardened for tropical campaigns.

Despite some opposition to their introduction, most notably from JR Kinghorn, the curator of reptiles at the Australian Museum who predicted dire consequences for native fauna, introductions throughout the wet tropics were made. It is now well known that the cane toads did not adequately control the cane beetles. Ironically, the cane toad was to become an even greater pest!

The problem with toads is that they are toxic to most wildlife that attempt to eat them and they reach such high densities that they impact on food resources available to the native fauna.

Remarkable invader

The cane toad has some amazing biological features that make it a very effective invader. All growth stages contain bufotoxins, a complex cocktail of toxins that are lethal to many animals. The composition and strength of these toxins varies during the development of toads, but few vertebrate predators in Australia can tolerate them sufficiently to include toads in their diet. The parotoid glands of toads on the rear of the head contain the most bufotoxin, but toxins are also spread elsewhere in the body.

Most of the cane toad diet consists of insects, but they have been recorded to eat other frogs, small mammals and reptiles, snails and fruit. They even raid dog food from backyards.

Their reproductive potential is nothing short of mind boggling. A female can produce up to 30,000 eggs in a clutch and she may produce two of these in a year. It takes less than a year for a toad to reach reproductive maturity. Thankfully, there is high mortality of the eggs, tadpoles and metamorphs (the first stage living on land) due to predation, most often by other cane toads. Nonetheless, they have the ability to rapidly increase the size of local populations.

The invasion of Australia has not been without compromise for the cane toads. Work by researchers at the University of Sydney comparing toads from the invasion front with those back in Queensland found that the toads have evolved to be larger

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Main Channels and grassland in the Ord irrigation area will provide excellent habitat for cane toads.
Photo – David Pearson/DEC
Inset Cane toad.
Photo – Jiri Lochman

Above The potential impacts of cane toads on Kimberley frogs, such as Weigel's spadefoot, which is confined to the north Kimberley and was only described in 1987, are unknown.
Photo – David Pearson/DEC

Left Deadly bufotoxin exuding from the parotoid glands of a cane toad.
Photo – Jiri Lochman

Above Northern quoll populations in the Northern Territory have been devastated by the arrival of cane toads.
Photo – Jiri Lochman

Left The small skink *Carlia johnstonei* is one species that shows no interest in eating toad metamorphs.
Photo – David Pearson/DEC

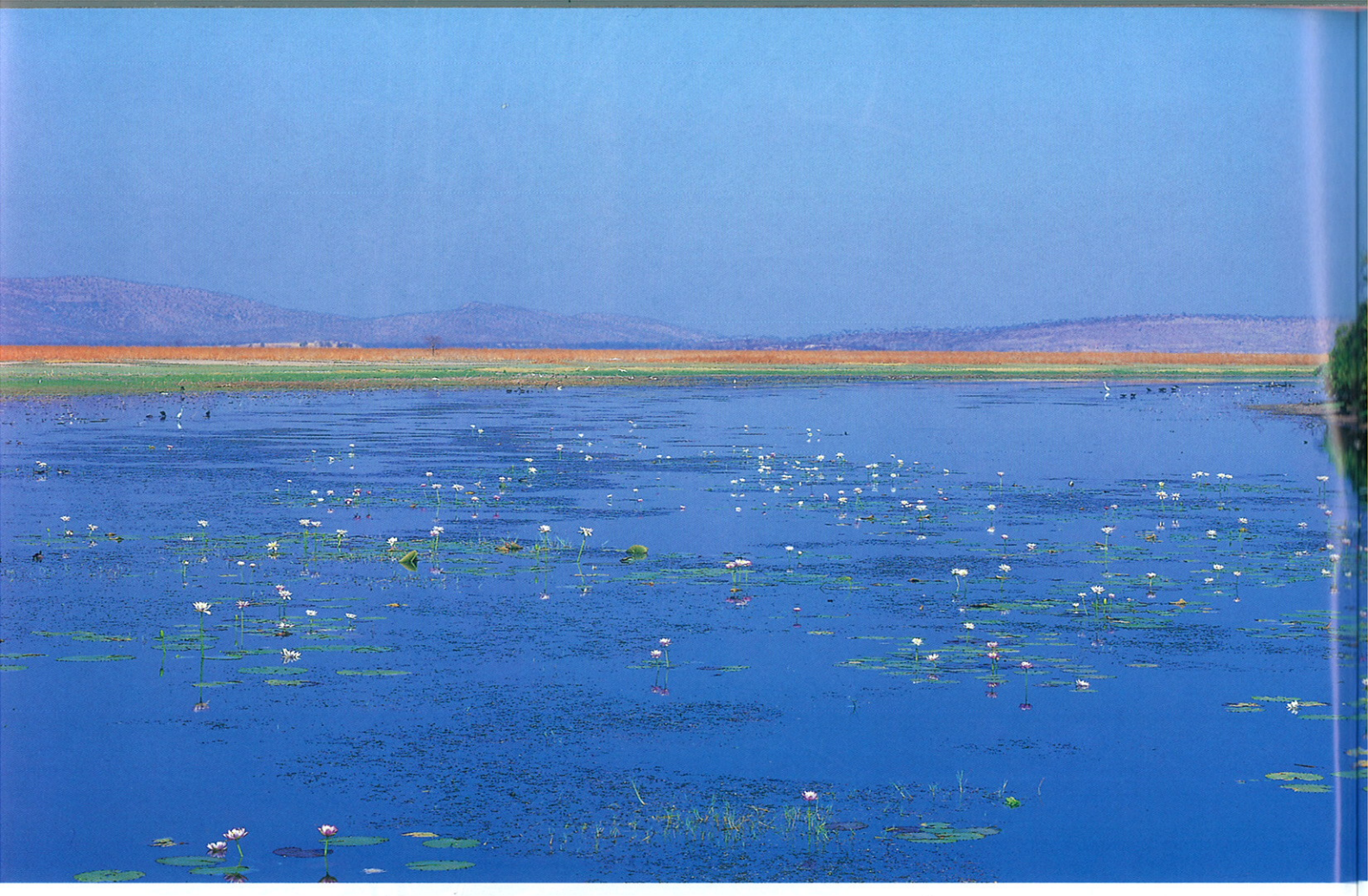
and have longer legs. This would be advantageous for the pioneer toads as they scramble across the country trying to keep a step (or swamp) ahead of their fellow toads. When they breed, more of their progeny are likely to survive in the absence of competition from other cane toads.

However, the stress of their cross-country marathon is playing havoc with the toads' bodies. Working with the University of Sydney team, Northern Territory vet Cathy Shilton found that toads hopping at the front of the pack often developed an arthritic-like condition. This is the result of swelling of joints along the backbone due to a soil-borne bacterium that, under normal circumstances, is not a problem for toads.

An often-asked question about cane toads is how they are able to reach such densities and whether anything can eat them. In their original South American habitats there are a range of predators (other frogs, snakes, lizards, birds and mammals) that have co-evolved with cane toads and are able to cope with their toxins. Most Australian predators can't tolerate those poisons, so toads reach much higher numbers in newly invaded areas than in their ancestral range.

Understanding the toad

Professor Ross Alford and his group at James Cook University in Townsville have examined interactions between native fauna and cane toads, as well as radio-tracked toads to document their movements. Subsequent work by a University of Sydney research group led by Professor Rick Shine at Fogg Dam (near Darwin) has found that the biology of the toads at the invasion front varies markedly from those of long-established populations such as those near Townsville. Invasion front toads are all adults and behave differently. While north Queensland toads tend to move only short distances in random directions at night and during their

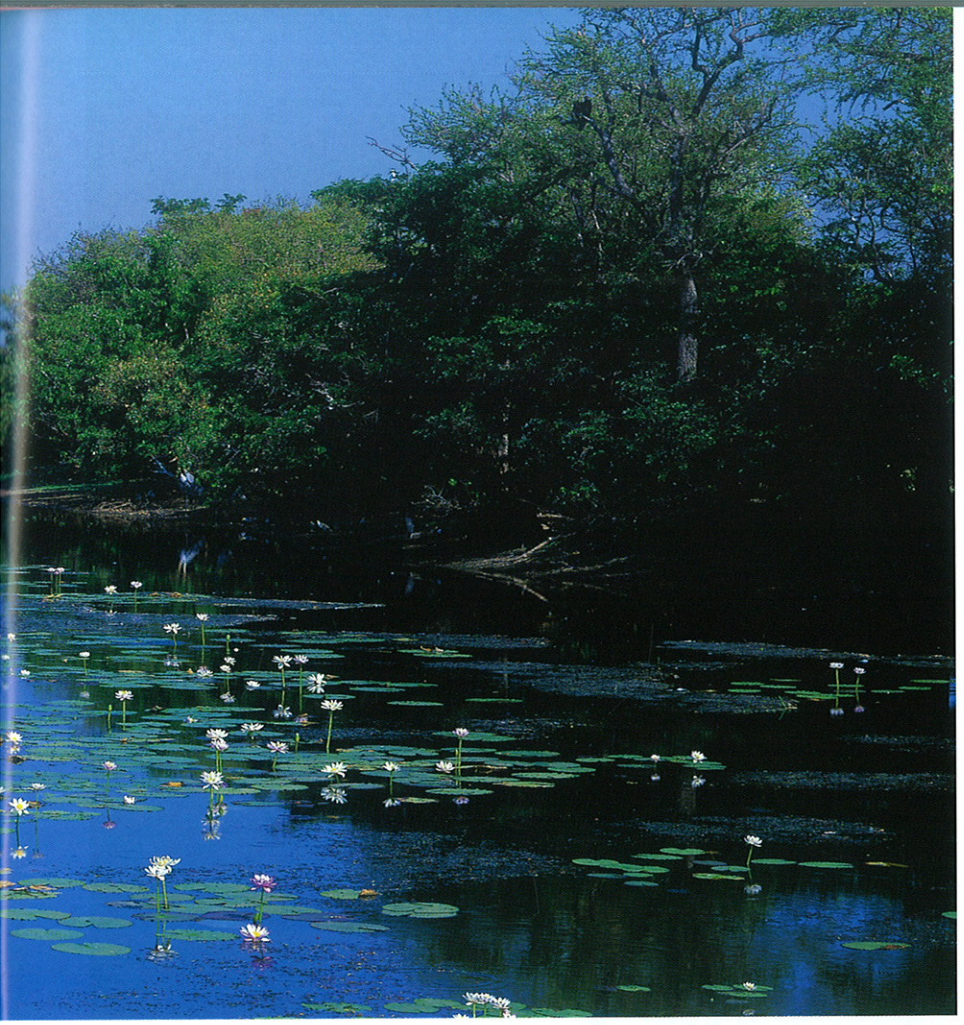


Above Cane toads will reach Marlgu Billabong in Parry Lagoons Nature Reserve within the next few years. It is situated near Wyndham and is an internationally recognised wetland.
Photo – David Bettini

Left Cane toads have an extraordinary ability to breed rapidly and produce large numbers of young.
Photo – Raoul Slater/Lochman Transparencies

lifetime, the invasion front toads are driven to keep moving in a west and north-west direction. They do not stop to form local breeding populations—they breed opportunistically then keep moving. Those on the front approaching WA are moving at an average rate of about 50 kilometres a year, but this rate varies with the intensity of the wet season (see 'Toad of a problem', *LANDSCOPE*, Spring 2005). This obviously has important implications for the control of toads, because toads removed from a site are likely to be rapidly replaced by toads advancing behind them.

In the Northern Territory, there are ongoing attempts to limit the spread of cane toads into Darwin and reduce their densities in urban areas.



Determining cane toad impacts

Some research on the impact of cane toads on native fauna was conducted in the Gulf Region of the Northern Territory and later in Kakadu National Park. That work found that the toads' effects were difficult to ascertain using usual methods, but goannas and some dragon lizards suffered significant population declines when toads arrived in a new area. Large numbers of dead freshwater crocodiles have been reported when toads first arrive, but the longer-term impact on populations is unknown.

The Northern Territory Government has recognised the plight of northern quolls and has translocated quolls to several toad-free offshore islands to preserve some of the genetic diversity of the Northern Territory populations. Islands are not totally safe from toads as flooding from rivers can carry debris and toads in freshwater plumes well out to sea. Toads also stow away in boats and in goods transported to islands.

Studies which have attempted to examine the impact of toads on fauna by surveying native animals before and after the arrival of toads have generally been inconclusive. Variation in capture rates and animal activity due to weather and seasonal differences make it difficult to interpret what is a cane toad-related impact or normal variation. In addition, toads are likely to impact on predatory species that occur at low densities and are rarely seen or captured during survey work.

Many Kimberley species have been identified as potentially threatened by cane toads. Field monitoring of all these species would be extremely difficult and costly, so a means to rapidly assess species most threatened by the toad invasion was required. An Australian Research Council (ARC) linkage project involving the University of Sydney, the Western Australian Department of Environment and Conservation (DEC), the Federal Department of Environment, Heritage, Water and the Arts and the Australian Reptile Park is seeking to determine those species needing urgent conservation attention and those that are robust enough to withstand the arrival of toads.

Under the 'toad impact' project, small numbers of native species that have had no prior exposure to toads are captured in the Kimberley and sent to the University of Sydney research facility at Fogg Dam. Here, in laboratory trials, the feeding responses of the native predators to toads are determined. To date, the study has tested a range of species potentially affected by cane toads including dragon lizards, goannas, venomous snakes, pythons, dasyurids (carnivorous marsupials) and rodents. Reactions to toads vary considerably between species. Experimental studies in the laboratories have been informative, especially when the experiments can be followed up with field trials. Several species show no interest in eating toads, others are able to avoid the most toxic parts of the toads when they eat them and some species learn to avoid toads as long as their first exposure is not fatal. This raises the possibility that we can train native predators to avoid toads and research is continuing in this area.

While no species are known to have become extinct due to cane toads, we know little about the impact of toads on some faunal groups such as invertebrates. There is concern that the toads could have disastrous impacts on endemic land snails that occur in limestone ranges to the north and north-east of Kununurra. The ancestors of these land snails arrived in Australia about 12 million years ago from Asia and have spread and evolved into many more species in Australia. Increasing aridity has confined them to refuges which in turn led to further speciation. Many of these snails now live in areas of only a few hectares and laboratory studies have shown that toads will readily eat them. Researchers are now trying to assess if toads will actually encounter snails frequently enough in the wild to pose a serious threat to their conservation.

An extensive biological survey of Kimberley islands is currently under way by DEC, with assistance from the Australian Government (see 'Treasures of a sunken coastline', *LANDSCOPE*, Winter 2008). This survey will collect information on which islands harbour populations of species such as quolls and goannas that are likely to be seriously affected by toads. Some of these islands may provide toad-free sanctuaries for fauna.

Stopping the march of the toad

The arrival of toads in Kakadu National Park in 2000 focused attention on their ongoing and rapid spread.

Above Threatened land snails in a limestone crevice in the Ningbing Ranges. *Photo – David Pearson/DEC*

Until then, there had been no efforts to control toads by physical means such as trapping, fencing or by directly catching and killing toads. Community disquiet about the advance of toads saw Frogwatch Northern Territory develop cane toad traps and draw public attention to the toads.

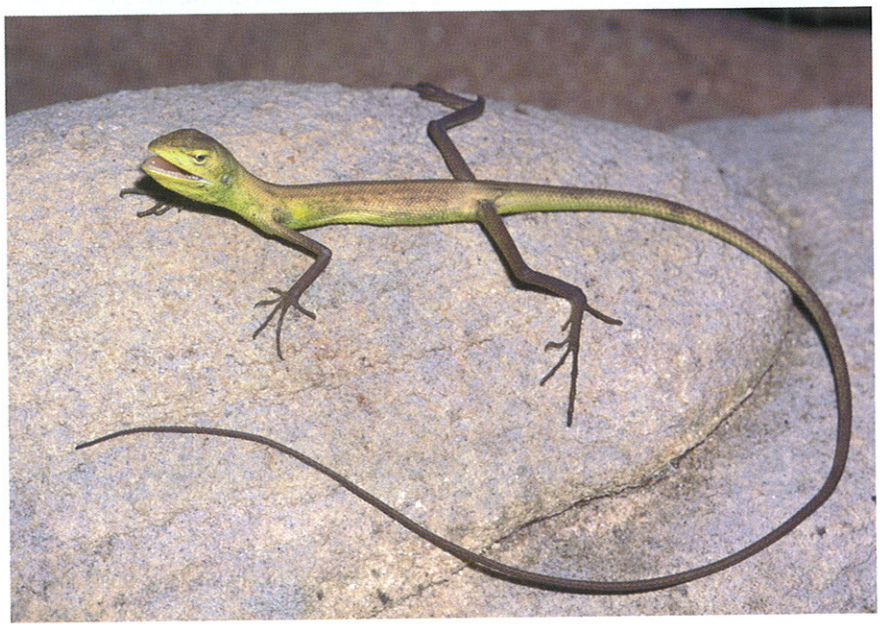
In December 2004 the Western Australian Government started its State Cane Toad Initiative, including a surveillance team operating primarily in the Northern Territory, enhanced border inspections, trapping trials, public education and investigations into control options. The objective was to fight the invasion and, if possible, delay the toads' advance until an effective biological control program could be implemented. This initiative has been funded to 2010.

In March 2005, a meeting was held in Kununurra to discuss stopping the advance of toads. This led to the establishment of two community groups, the Kimberley Toadbusters and the Stop the Toad Foundation. These groups have set about trying to prevent toads reaching WA. Kimberley Toadbusters organise regular 'toad-busting' trips into the Northern Territory to collect and euthanase toads, tadpoles and metamorphs. This voluntary group is also active in educating local communities about toads and involving Aboriginal communities in toad-busting activities. The Stop the Toad Foundation has focused its attention on public education, and organises an annual toad muster using large numbers of volunteers. This group has also trialled different trap and fence designs.

DEC maintains a cane toad control group of five people and the world's first cane toad detection dog, called 'Nifty', based in Kununurra. The team works closely with the Department of Agriculture and Food to prevent 'hitch-hiker toads' arriving in WA, to provide information to the public, work with community groups, map the distribution of toads and undertake specific control of populations by trapping and hand collection.

Professor Tony Peacock of the Invasive Pest Cooperative Research Centre reviewed the efforts of community groups in stopping the spread of cane toads for the Western Australian Government. He found that there was no evidence that 'toad-busting' activities had slowed the advance of the toads, but the groups had been successful at stimulating the public's awareness and interest in toads and their impacts and had provided examples of unprecedented community involvement in attempting to solve an invasive species problem.

While toad-busting cannot permanently eliminate toads, it can reduce the numbers of toads in localised areas. There may be a future for communities to cooperate to force toads into low densities at key sites, provided efforts can be maintained over time.



Top The mulga snake is a large predator that is likely to eat large toads.

Above The superb dragon only occurs in the Kimberley and does not appear to eat cane toads metamorphs.
Photos – David Pearson/DEC

Why not use a biological control agent against toads?

Biological control captures the public imagination as the ideal way to control pest species. It is viewed as highly specific to the pest, self perpetuating, landscape-wide and cheap to apply. The only real examples of successful broad-scale biological control of a vertebrate species are the use of the diseases myxomatosis and calicivirus to reduce rabbit populations.

In 1986, a council of Australian Government environment ministers funded a project to identify potential diseases and parasites in Australia that might be used to control cane toads. Unfortunately, no suitable control agent was found. In 1990, a team of CSIRO scientists went to Venezuela to search for a suitable biological agent in native habitats of cane toads. They isolated a number of viruses (ranaviruses) that affected cane toads, but testing showed that these viruses were deadly for native Australian frogs and so unsuitable for release. This project ceased in 1996, but the search for a biological control agent recommenced in 2000. CSIRO scientists explored the idea that an existing virus could be modified to contain a gene that could interfere with metamorphosis in toads (the transition from tadpole to toad). This research aimed to find the protein responsible for the process and eliminate it from tadpoles. Concerns were raised, however, that even if a suitable way of preventing metamorphosis were discovered, a means to spread the virus would need to be found. In addition, exhaustive testing would be needed on a range of native frogs to ensure such a virus did not cause the death of native species. And, even if everything worked out to produce a specific toad-killer, what would happen if the virus escaped to the toad's native range? So, the obstacles to successful use of a genetically engineered virus for toad control are enormous and recently the Australian Government discontinued funding this research.

Any hope for the future?

It may appear that the future for Kimberley fauna is bleak with no proven way to stop the advance of toads and possible catastrophic effects on many species. However, there is hope. Some native bird and mammal species are resistant to bufotoxins. Indeed, all the rodent species tested are highly resistant to toad toxins, and some species eat toads but avoid the most poisonous parts. Small carnivorous dasyurid marsupials, such as planigales, learn from their first encounter with toads and refuse to eat them thereafter.

Recent research has identified a number of techniques that could reduce densities of cane toads and

Left Native mosaic-tailed rats eat cane toad metamorphs without apparent ill effects.
Photo – Jonathan Webb

their impact on native predators. A lung roundworm (a nematode of the genus *Rhabdias*) has been found in many toads and it acts to reduce their growth rates and kill large numbers of metamorphs. Species of *Rhabdias* are also found in native frogs, but genetic analyses have found that the species infecting cane toads is originally from South America and appears unable to infect native frogs in the wild. The use and propagation of this parasite is currently under further investigation, with the hope it may prove suitable for releasing at the toad invasion front to effectively slow toads and reduce their breeding success.

For localised control, pheromones that attract toad tadpoles or cause them to flee, but have no impact on native tadpoles, offer hope of a means to remove cane toad tadpoles from dams, smaller water bodies or areas of high conservation value. Various genetic strategies are also under investigation, but these involve scientific fields in their infancy and would require enormous funds and operational scales never before witnessed, without certainty of their success in the 'real world'.

Despite efforts to control or slow the spread of toads, native predators will still encounter toads and so techniques to ensure the survival of their populations are required. Training native predators to avoid toads through the use of small sterile toads or parts of toads is currently being investigated.

Living with toads

Unfortunately, despite effort, it appears that for the immediate future at least people in the tropical north of WA will need to learn to live with toads. It will be possible for people to keep their backyards relatively free of cane toads by their regular removal. Cane toads find it easier to move through open country and breed most successfully in waterbodies with little vegetation around them. Thus, improved land management is needed, especially in relation to fire, so that more vegetation cover is retained both to maintain healthy populations of native predators and to discourage cane toad dispersal and breeding.

DEC is reviewing the State Cane Toad Initiative to guide efforts against cane toads once they reach WA. A stakeholder working group has been formed with representation from government, industry, Indigenous and community groups to assist in the development of this new strategy.

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Rick Shine is a professor in biology at the University of Sydney and a Federation Fellow of the Australian Research Council. He heads a large research group studying the ecology and conservation of Australian animals, mostly reptiles. For details of his team's research on cane toads, see the website www.canetoadsinoz.com.

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