Controlling the spread of cane toads requires an integrated approach that uses more than one control method

A submission to the Parliamentary inquiry into controlling the spread of cane toads

Prof. Mike Letnic* (University of New South Wales), Assoc. Prof. Tim Dempster (University of Melbourne), Assoc. Prof. Jonathan Webb (University of Technology, Sydney), Dr Tim Jessop (Deakin University), Assoc. Prof. Heloise Gibb (La Trobe University), Dr Benjamin Feit (Swedish University of Agricultural Sciences)

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(a) Impacts and spread of cane toads

The introduction of cane toads into Australia in 1935 is one of the nation's worst ecological tragedies. Cane toads are prodigious breeders, have been highly effective at expanding their areas of occupation and above all are toxic to many of the native predators that attack them (Fig. 1). Consequently, the invasion of cane toads has devastated populations of goannas, freshwater crocodiles, snakes and quolls across the continent (Letnic et al. 2008; Shine 2010; Feit & Letnic 2015). These effects that toads have had on ecosystems appear to be long-lasting, as populations of goannas and freshwater crocodiles have shown little sign of recovery in the decade since toads invaded riverine habitats in the Northern Territory (Doody et al. 2017; Fig. 2.).

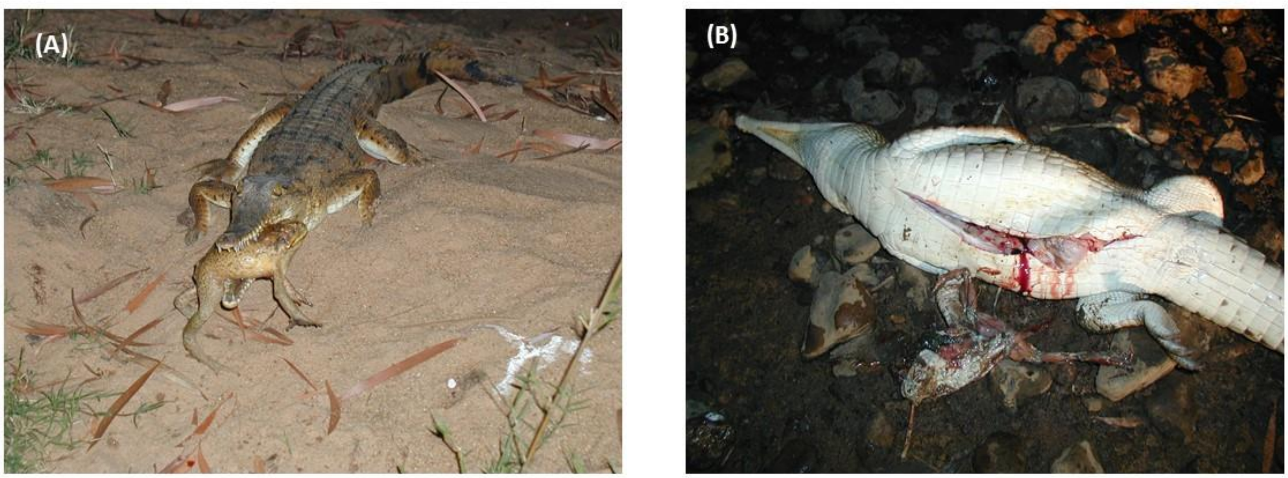
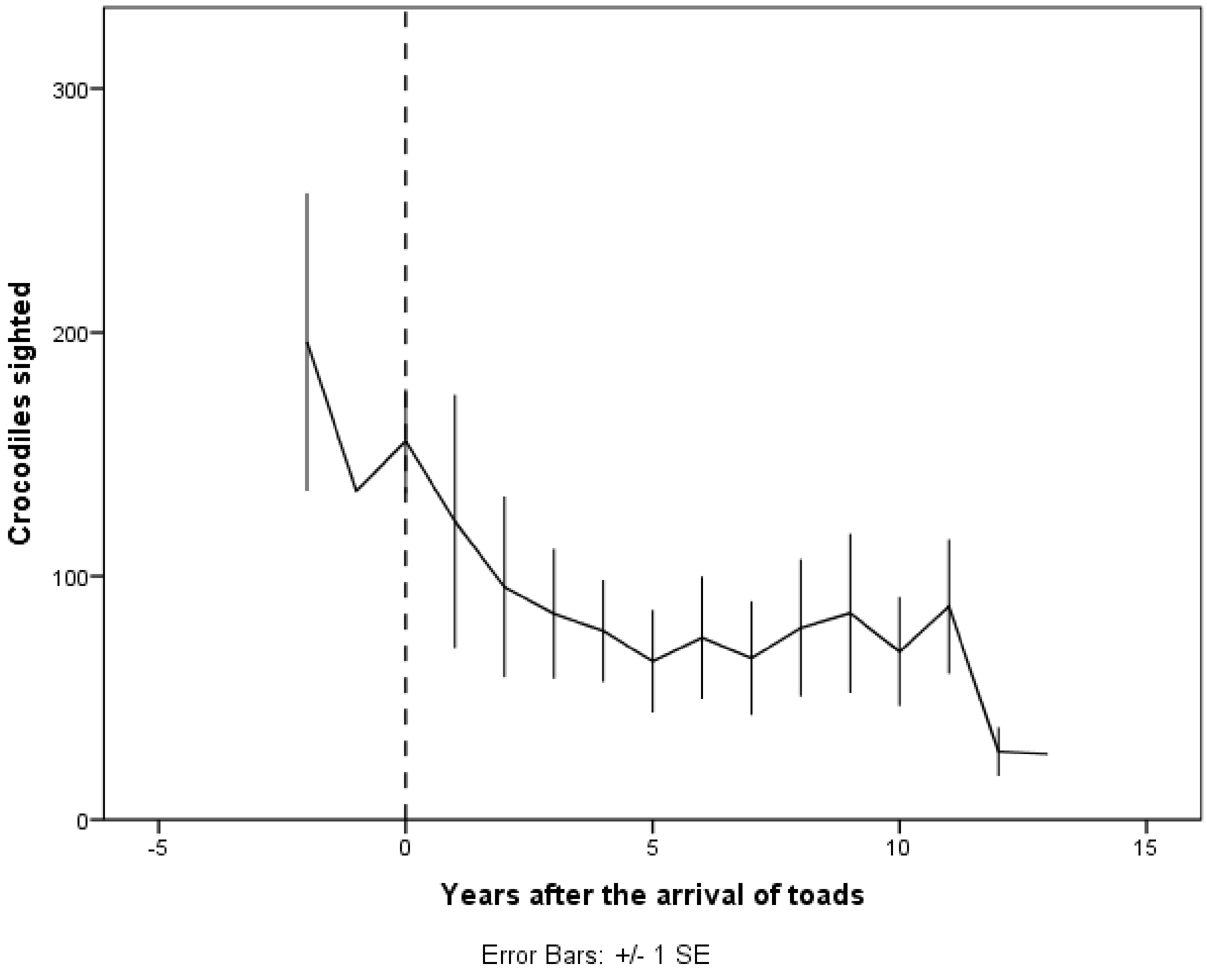


Figure 1. (A) This freshwater crocodile has captured a large cane toad. (B) This freshwater crocodile was killed by ingesting a cane toad

Figure 2. Graph showing the average number of crocodiles sighted during spotlight surveys conducted on 4 water-holes on the Victoria River, Northern Territory up to 2 years before the arrival of cane toads and 13 years after the arrival of toads. The dashed line indicates the year when toads arrived. Crocodile numbers have declined dramatically since the invasion of toads and show no signs of recovering. Surveys of crocodiles commenced in 2005 and have been conducted each year since.



Dung beetles were introduced to Australia to improve nutrient cycling in rangeland ecosystems and disrupt the life-cycles of livestock parasites. Their introduction is widely regarded by pastoralists as one of the most important and successful government assisted programs to improve production. However, predation by cane toads has reduced the important ecosystem services that dung beetles provide for the environment and pastoral industry. Cane toads have been nothing short of disastrous for the Australian environment.

(A) (B)

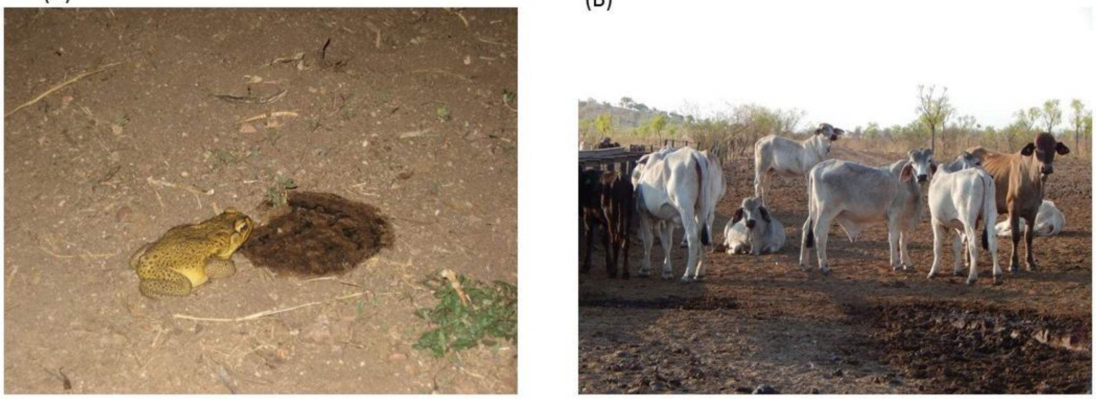


Figure 3. (A) Cane toad feeding on dung beetles at a fresh cow pat. (B) Dung beetles were introduced to northern Australia to speed-up the breakdown of cattle dung and in so doing improve nutrient cycling and disrupt the life-cycles of cattle parasites.

At present, cane toads have occupied about ~2 million km^2 (over 25%) of Australia and continue to invade west and south. While many people think of cane toads as being tropical animals, most of the area that cane toads have invaded or are predicted to invade has a semi-arid or arid climate. Considerable effort has been spent on controlling cane toad populations and preventing their spread. These efforts have included the development and trialling of biological control agents (e.g. viruses and parasites), pheromone traps to capture tadpoles, and simple but laborious collection of toads by hand. Despite enormous efforts expended on cane toad control, at best they have only achieved minimal population reduction at small-scales and appear entirely ineffective to limit ongoing invasion across Australia.

(b) Controlling the impacts and spread of toads in semi-arid regions

Our research has focused on developing and testing effective methods to control cane toad populations, prevent their spread and, most importantly, reduce their impacts at scales meaningful to biodiversity conservation and agricultural production. We have focused our research on semi-arid ecosystems, which toads have only recently invaded but comprise most of the area of Australia that toads will eventually invade. Our long-term goal is to provide new strategies that land-mangers can use to protect Australian ecosystems from the ravages of cane toads. Our study sites are located in the rangelands of the Victoria River District and Tanami Desert in the Northern Territory. The findings summarised below were produced by large-scale labour-intensive studies, which manipulated cane toads' access to water, followed the fate of cane toad populations, dung beetles and cow dung or used telemetry and physiological assessments to understand the "natural history" of toads and identify their "Achilles Heel".

The cane toads' invasion of semi-arid Australia has been facilitated by the creation of artificial water points. Cane toads cannot survive for more than 3 days during periods of dry conditions that normally prevail in arid Australia without access to water (Webb et al. 2014; Florance et al. 2011; Jessop et al. 2013). Natural sources of water are normally scarce in arid regions. However, dams created by pastoralists that serve as reservoirs for bore-water, have dramatically increased the availability of water in naturally parched semi-arid landscapes (Letnic et al. 2014). Dams therefore provide a network of refuge habitats or "invasion hubs" in which toads congregate during dry seasons and visit on an almost daily basis (Webb et al. 2014; Letnic et al. 2014). Our research shows that a single dam can support more than 1000 toads (Figure 5; Florance et al. 2011). Following rains, toads venture away from the dams until the landscape begins to dry out when they converge on dams once more (Letnic et al. 2014).

Figure 5. Cane toads sitting out the daytime heat in the water on the edge of a dam in the Victoria River District of the Northern Territory. Cane toads need the water that dams provide to rehydrate. Toads quickly die when they are excluded from dams. A single dam can support more than 1000 toads.

Cane toad populations at artificial water points can be effectively controlled and even eradicated by preventing them from accessing water. Using simple fences constructed of shade cloth (Fig. 6), we demonstrated that toads could be eradicated from dams. By maintaining the fences for one year, we showed that water exclusion enables sustained control of cane toad populations and prevents their reinvasion (Florance et al. 2011; Letnic et al. 2015). This method caused local extinction of the toad population.

Figure 6. Cane toad proof fence installed around a dam in the Victoria River District of the Northern Territory. This fence enabled the eradication of toads from this dam. Toads living within the fenced area were collected and any toads that came to the dam died of dehydration because they were unable to access the water.

Excluding cane toads from water by using an alternative type of reservoir to dams is a practical approach to reduce cane toad populations and their impacts on native predators and the pastoral industry. Across Australia, two types of water reservoir are widely used to hold water which is pumped from underground bores. The most widely used type of reservoir are earthen dams (Fig 7A).

Figure 7. (A) An earthen "turkey nest" dam and (B) a steel tank. Both of these reservoir types provide bore-water to livestock via a trough that is fed by gravity. Dams provide toads with an unlimited source of water and can support more than 1000 toads. In contrast, tanks support very few toads because toads can only access water from leaks in the tanks or the pipes that supply them. Thousands of bore-fed dams exist across arid Australia. These dams function as stepping stones that have allowed toads to invade semi-arid regions of tropical Australia. Cane toads' impacts on goannas and dung beetles are greater in the vicinity of dams than tanks due to the greater numbers of toads that inhabit dams.

The other reservoir type are tanks made of either plastic or steel (Fig. 7B; Letnic et al. 2014). In comparison to dams, tanks provide toads with little opportunity to access water and therefore support lower numbers of cane toads than dams and the numbers of toads decrease with distance from water (Feit et al. 2015; 2018). Consequently, toads' predatory impacts on dung beetles is greater and the rate of cattle dung breakdown is lower at dams than tanks. Goannas (Fig. 9) also occur in higher numbers in the vicinity of tanks than dams, presumably because the rate of encounters with toads is lower near tanks (Feit et al. 2018). In turn, small lizards preyed upon by goannas occur in higher numbers near dams because there is less predation pressure from goannas (Feit et al. 2018). Taken together, these findings show that using tanks, an alternative to dams, as reservoirs at AWP can effectively reduce toad numbers and their impacts on populations of dung beetles and goannas (Feit et al. 2015; 2018).

Excluding toads from water could be conducted strategically to prevent their spread and control existing populations. Across large areas of inland Australia, the main water sources available for toads during dry periods are artificial water points (Florance et al. 2011; Fig. 8). Our simulation study investigating the potential for toads to disperse away from their dry season refuges (invasion hubs) suggested that cane toads could be controlled in landscapes that are naturally waterless in dry seasons by systematically excluding toads from water to create "toad-breaks" (Florance et al. 2011). Strategically positioned toad-breaks could thwart the invasion of toads if the straight-line distance across them exceeds the "wet-season" dispersal potential of toads, so that toads which attempt to traverse them cannot find water and perish (Florance et al. 2011; Letnic et al. 2014, 2015). Mapping of artificial water points across arid Australia, shows that there is great opportunity to control the spread of cane toads into the Pilbara region of WA by restricting their access to water along the coastal strip of the Great Sandy Desert. In this region there is little natural water and few artificial waters (Figure 8). The artificial waters that do exist occur in a narrow corridor along the coastal highway and could be modified to prevent toads from accessing the water (i.e. by installing tanks or installing toad proof fencing), and in so doing create a ‘toad-break” that could prevent the southward spread of toads towards the biodiversity rich gorges of the Pilbara (Florance et al. 2011; Tingley et al. 2015). Our simulations also show that restricting toads’ access to water could contain their spread in the regions between Tennant Creek and Alice Springs, and in south-west Queensland (Fig. 8).

In addition to constraining the spread of toads, water exclusion could also be used to strategically control existing populations of toads in dryland areas (Letnic et al. 2015). This could be done by simply closing water-points where they are not needed for commercial purposes or by changing earthen tanks to dams or fencing earthen dams (Letnic et al. 2014; 2015). Implementation of such approaches could effectively reduce cane toad populations and their impacts across vast areas of inland Australia where natural sources of permanent water are scarce.

(2) Practical relevance and benefits

Excluding toads from water - a practical way to control toad populations. The presence of human-made dams has allowed cane toads to invade otherwise waterless landscapes. To date, no effective control for cane toad populations has been implemented. Our research has demonstrated that restricting cane toads’ access to water is an effective and practical way to control their populations and reduce their impacts (Letnic et al. 2015; Feit et al. 2015; 2018). These findings are significant because most of the area that is left for cane toads to invade in Australia is semi-arid.

We have shown that there is more than one-way to exclude cane toads from water (Letnic et al. 2015; Feit et al. 2015; 2018). Dams could be fenced to exclude toads, or different types of reservoirs such as closed tanks which do not allow toads to access water could be used as alternative types of reservoirs to dams. Although each of the approaches to control cane toads we have demonstrated has its pros and cons, both the fencing of dams or the using of tanks as an alternative to dams have the potential to be used in landscape scale programs to control cane toads. Importantly for the practical application of these findings, the approaches we have devised do not impinge on the ability of livestock to obtain water, because in most situations in northern Australia, livestock drink from troughs and not the dams themselves. Also, the native fauna of arid Australia are arid adapted and thus unlike cane toads are not dependent or unduly impacted by exclusion from artificial water sources.

Fencing the thousands of dams that exist across Australia to exclude cane toads is a daunting and prohibitively expensive prospect. However, using simulations we have shown that a practical and cost-effective approach to control cane toads would be to strategically create “toad breaks” to disrupt the network of refuge habitats available for toads (Florance et al. 2011). Just like a fire-break can contain a bush-fire by preventing its spread by denying fuel to the fire, toad breaks could be established in areas distant from natural sources of water in places where it would be feasible to exclude toads from water and establish water-less tracts of land which toads could not traverse without perishing. Control of toads at invasion hubs could be conducted reactively, to control established populations, or prevent the spread of toads, by rendering invasion hubs unsuitable for colonization ahead of the invasion front (Letnic et al. 2015).

Figure 8. Map showing the distribution of artificial waters (red) and natural waters (blue) within the area of semi-arid Australia that is predicted to be invaded by toads (grey). Each water has had a buffer drawn around it reflecting the dispersal potential of toads. The orange portion of the map indicates the area that our simulation exercise identified could be made unavailable for toads by excluding them from artificial water points. The boxes highlight regions, where strategically excluding toads from artificial water points is predicted to be a particularly effective method to control cane toads including in (A) the coastal strip of the Great Sandy Desert.

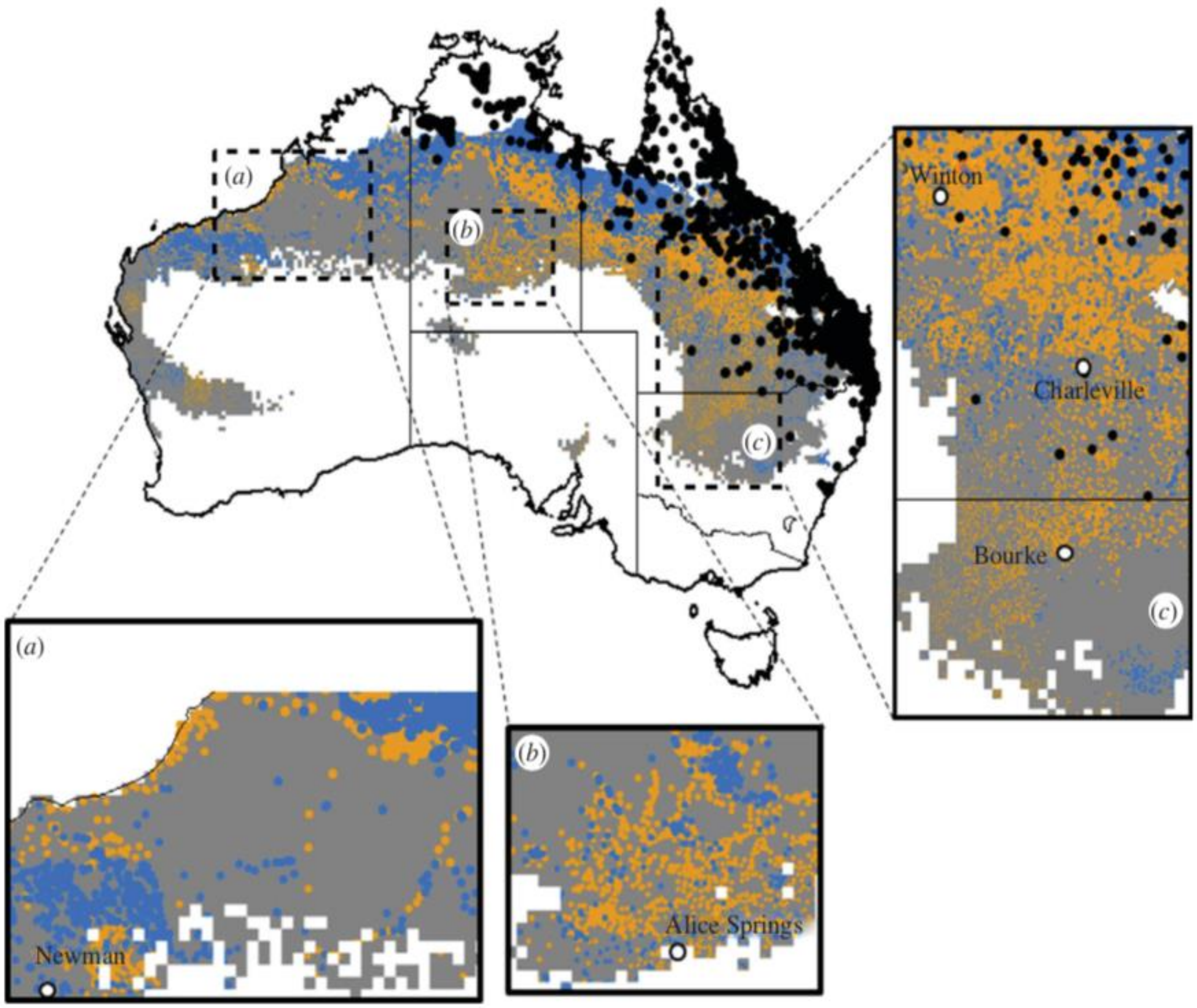


Figure 9. This large goanna (*Varanus panoptes*) was photographed on the Victoria River in 2005, two years before the invasion of cane toads. At this time, goannas were an important source of "bush-meat" for Aboriginal people living in the region. These goannas have become rare since the invasion of toads and are now rarely caught by Aboriginal people in the Victoria River District.

Environmental benefits from excluding toads from water. We have shown that restricting toads' access to water can enhance the function of ecosystems in Australia's rangelands because it reduces toads' predatory impacts on dung beetles (Letnic et al. 2015). In areas with high cane toad numbers, dung beetle numbers are suppressed by cane toads leading to lower rates of dung breakdown. The breakdown of cattle dung by dung beetles is vital to promote nutrient cycling in rangeland ecosystems and also helps to reduce the parasite burdens of cattle (Feit et al. 2015). Impacts of cane toads on other invertebrate prey remain virtually unstudied, but may be significant.

By reducing cane toad numbers, restricting toads' access to water is also expected to relieve their impacts on native predators because it should reduce the frequency of fatal encounters between predators and toads. Across much of northern Australia, Aboriginal people hunt goannas on land that is also used for cattle grazing that has been provisioned with artificial water points. Reducing toad numbers and thus increasing goanna numbers is expected to benefit Aboriginal hunters by translating to increased hunting success rate for goannas. For many people in northern and central Australia, hunting is an important source of nutrition and calories and a culturally significant activity.

What is needed for the future?

Cane toads have had dramatic and long-lasting effects on Australian ecosystems. While no species have become extinct due to toad invasion, research shows that populations of native predators have persisted following toad invasion but have not recovered. The decline of these predators has had domino effects evidenced by increases in the numbers of animals normally preyed upon by these predators. Cane toads have also suppressed the economic services provided by dung beetles which were introduced to improve nutrient cycling in the rangelands and control parasite loads in cattle.

Considerable effort has been spent investigating approaches to control cane toad populations and prevent their spread, yet none have proved effective at landscape scale. Key reasons why these methods have not worked is that many are only suitable for controlling toad populations at small scales (i.e. a small wetland of interest), there has been insufficient investment, and a belief that a "silver bullet" cost-effective technique such as a biological control is inevitable.

Looking forwards, the effective control of cane toad populations will require an integrated approach that relies on having more than one method available and funds to implement control programs across a range of land-tenures. The advantage of integrated approaches is that different techniques will have advantages and disadvantages in different situations and in many situations their effects on toad populations are likely to be complementary. Water exclusion, for example, has great potential to control toad populations in arid areas but is much less effective in higher rainfall regions because in these regions there are many natural sources of water where toads can seek refuge during the dry season. Water exclusion will also require funds to establish and maintain water exclusions and political support to ensure that private stakeholders are on side.

The challenge ahead will be finding the funds to develop and implement a set of tools that can be used to effectively control toads in the many different contexts in which they live. Techniques such as biological control (e.g. a virus or gene drive using CRISPR) have great potential if they can be developed, but they will face technical challenges and legal and ethical issues. Therefore, we should not assume that their development is inevitable and commit funds solely for their development. Such an approach would delay the implementation of other practical methods. We know also from past experience with rabbits that relying on biological control agents alone did not achieve the desired objective and that integrated control which does not rely on a single control-technique is most effective. For example, rabbits are now effectively controlled in many regions of the country using a mix of techniques including biological control agents (myxomatosis and calicivirus), poisoning and physical control (destroying their burrows). No single technique has been effective because the efficacy of biological controls has waned over time due to evolution of resistance, the effectiveness of biological controls is dependent on climatic conditions, and much of the country is too remote for poisoning and burrow destruction.

It is our view that investment should target control of toad populations using a range of techniques including (but not restricted to) water exclusion, targeted control at breeding bodies (e.g. using pheromone traps) and hopefully in the future a biological control agent that demonstrably reduces toad population abundance.

Publications referred to in this submission

Doody, JS, Rhind D, Green B, Castellano C, Colin McHenry C, Clulow S. Chronic effects of an invasive species on an animal community. ***Ecology*** 98, no. 8 (2017): 2093-2101.

Doody, J.S., Soanes, R., Castellano, C.M., Rhind, D., Green, B., McHenry, C.R. and Clulow, S., 2015. Invasive toads shift predator–prey densities in animal communities by removing top predators. ***Ecology*** *96*(9), pp.2544-2554.

Feit B & Letnic M (2015) Species level traits determine positive and negative population impacts of invasive cane toads on native squamates. ***Biodiversity and Conservation*** 24, 1017-1029.

Feit B, Dempster TD, Gibb H, Letnic M (2015) Invasive cane toads' predatory impact on dung beetles is mediated by reservoir type at artificial water points. ***Ecosystems*** DOI: 10.1007/s10021-015-9865-

Feit B, Gordon CE, Webb JK, Jessop TS, Laffan SW, Dempster T, Letnic M (2018) Invasive cane toads might initiate cascades of direct and indirect effects in a terrestrial ecosystem. ***Biological Invasions*** accepted 19/9/2017.

Florance D, Webb JK, Dempster T, Worthing A, Kearney MR & Letnic M (2011) Excluding access to invasion hubs can contain the spread of an invasive vertebrate. ***Proceedings of the Royal Society of London B*** 278: 2900-2908.

Jessop T, Letnic M, Webb JK, Dempster T (2013) Adrenocortical stress responses influence an invasive vertebrate's fitness in an extreme environment. ***Proceedings of the Royal Society of London B*** 280: 20131444

Letnic, M, Webb JK, Shine R (2008). Invasive cane toads (*Bufo marinus*) cause mass mortality of freshwater crocodiles (*Crocodylus johnstoni*) in tropical Australia. ***Biological Conservation*** 141, 1773–1782.

Letnic M, Webb JK, Jessop TJ, Florance D, Dempster T (2014) Artificial water points facilitate the spread of an invasive vertebrate in arid Australia. ***Journal of Applied Ecology*** 51(3): 795–803.

Letnic M, Webb JK, Jessop TJ, Dempster T (2015) Restricting access to invasion hubs enables sustained control of an invasive vertebrate. ***Journal of Applied Ecology*** DOI: 10.1111/1365-2664.12390

Shine R. (2010) The ecological impact of invasive cane toads (*Bufo marinus*) in Australia***. Quarterly Review of Biology*** 85, 253–291.

Tingley R, Phillips P, Letnic M, Brown G, Shine R, & Baird S (2013) Identifying optimal barriers to halt the invasion of cane toads *Rhinella marina* in northern Australia ***Journal of Applied Ecology***50, 129-137.

Webb JK, Letnic M, Jessop TJ, Dempster T (2014) Behavioural flexibility allows an invasive vertebrate to survive in a semi-arid environment. ***Biology Letters*** 10: 20131014.