Living with *Bufo*

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ABSTRACT

Cane toads *Bufo marinus* have been in Australia since 1935. Originally hailed as the potential savior of the ailing Queensland sugar cane industry, toads are now viewed as a nuisance, a scourge and a threat to Australian wildlife. In this paper, I will track the history of cane toads in Australia and investigate the changing perceptions that have ensued. Cane toads frequently make headlines when they venture into new areas, sparking a new wave of public animosity and outrage. Questions addressed: Are these responses justified or is *Bufo marinus* merely a highly recognizable target for public anger? Will the recent detection of a second species of toad in Australia, the Asian Black-spined toad *B. melanostictus*, be greeted with the same response or will it be accepted as a new arrival?

Key words: Cane toad, *Bufo marinus, Bufo melanostictus,* introduction, community response, control measures.

Introduction

Despite being an introduced animal, cane toads *Bufo marinus* are amongst the best-known Australian animal (Tyler 1976; Meredith 1996). They have reached this exalted status because of an unusual public attitude to them. A "love-hate" relationship exists that is frequently fuelled by the media with provocative headlines and stories designed to keep festering public feelings stirred (Figure 1, see appendix 1). This animosity is widespread in indigenous and non-indigenous communities. For example, *Australian Nature* featured an article by Altman *et al*. in 2003 about the impending arrival of toads in Arnhem Land and the response of the indigenous people to the "invasion of the rubbish frogs'.

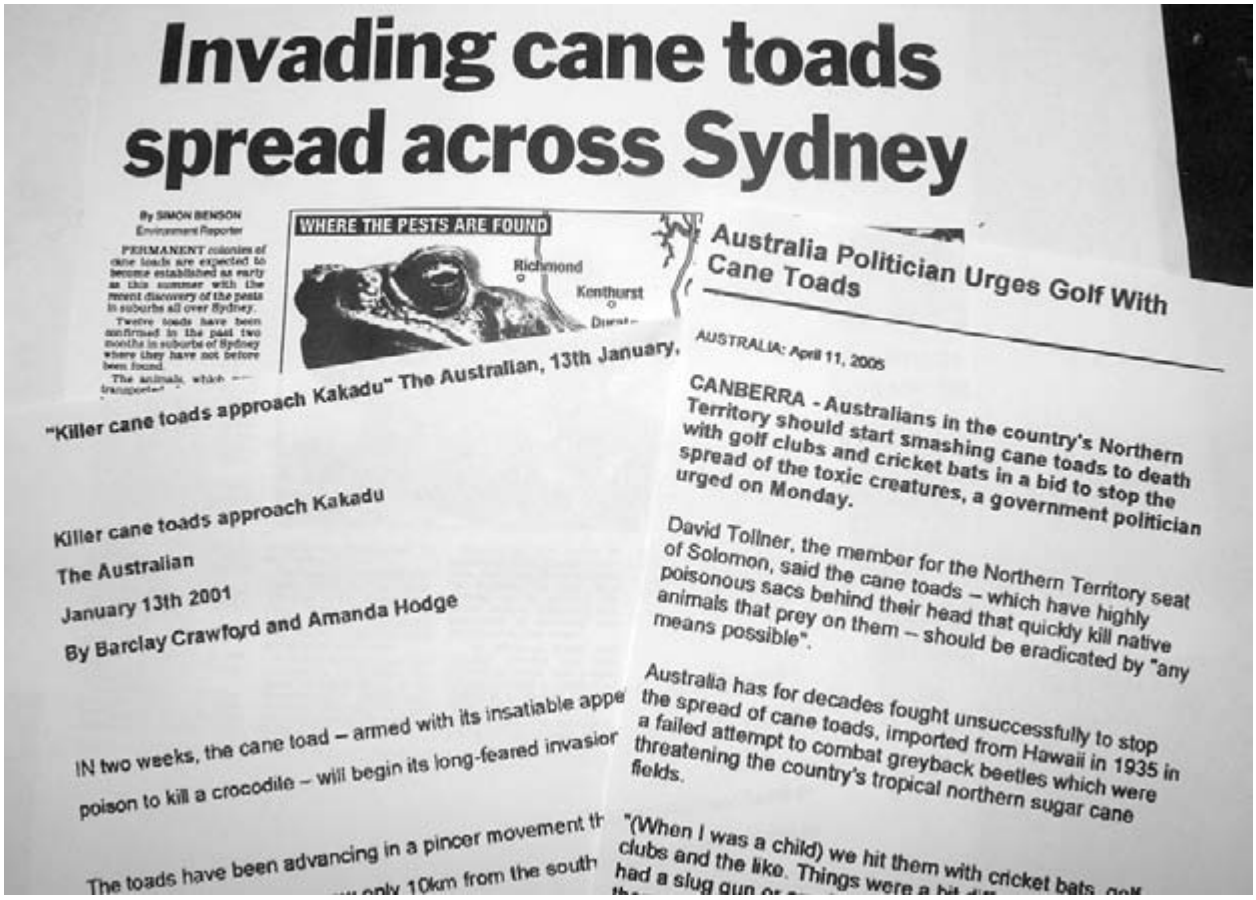

Figure 1. Recent headline articles describing cane toads in Australia.

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However, inflammatory media tactics can only work if there is already a widespread sensitivity about cane toads that can be easily exploited. That this sensitivity exists is beyond dispute, but how did it develop? There are many other exotic species in Australia but few engender the same passion amongst Australians as cane toads. To determine the basis for this animosity, we need to follow the history of cane toads in this country and to observe community reactions to them during this period.

Cane toads arrive

The importation of cane toads into Australia is a well-documented and well-recounted story (e.g. Tyler 1976, 1989; Meredith 1996). The toad was brought into Australia in an attempt to save the failing sugar cane industry in Queensland. Perhaps because toads were initially heralded as the potential savior of this industry, and failed, is the reason they quickly fell foul of public sympathy. But this is clearly not the whole story.

Cane toads were deemed to be needed to save the sugar cane industry as sugar cane stock infested with the grubs of cane beetles had been imported into Australian in the early 1900s. The beetles had survived and rapidly infested cane fields along the Queensland coast, decimating sugar production. Two species of cane beetle were initially blamed for the crop damage; Greyback Beetles *Lepidoderma sp*. and the Frenchi Beetle *Lepidiota frenchi* (Smyth 1916). Cane beetles flourished in the Australian cane fields with the perceived lack of an effective predator and sugar cane production continued to fall as a consequence of the damage the beetles caused. This was disaster for Queensland as the state was heavily reliant on sugar as one of its major income source. Cane toads were chosen as the solution to the problem because they had been used with some success in other parts of the world, notably in the West Indies, Philippines, Hawaii and Puerto Rica (Lonard 1933). The success of toads in Puerto Rica was reported in a letter to the editor of *Nature* in 1934 by Thomas under the heading "Toads save sugar crop". If cane toads were able to control cane beetles in these countries they should be able to do the same in Australia (Muntgomery 1935). From a political viewpoint, it would be a disaster not to try to help the floundering sugar cane industry (Tyler 1976).

On the 22nd of June 1935, a shipment of 102 cane toads arrived at Gordonvale in north Queensland from Hawaii. These toads were to be the founders of a captive-bred population that would later be released into cane fields throughout Queensland. The toads were transported under some fanfare from Gordonvale to the Sugar Experiment Station near Mareeba (Covacevich and Archer 1975). Sugar cane growers now waited in anticipation to receive batches of young cane toads for release in the cane fields.

Elsewhere in Queensland (and Australia), the advent of the cane toads was not so warmly received. There was a wide range of public concern about the importation of toads, some were exaggerated and far-fetched, some were quite reasonable and well voiced. The strongest counter campaign was mounted by the Queensland bee keepers. It was feared that cane toads would become a major predator of bees and that their industry would be threatened as a result of the widespread release of toads. Toads had been shown to congregate around bee hives and consume large numbers of bees as they emerged from the hive (Lever 1938). Similarly, poultry farmers were concerned that their hens might eat baby cane toads and become sick or die. Very few raised concerns about the impact of toads on native wildlife (Froggatt 1936).

However, it is important to note that there was already a growing resentment over the way that the cane industry was dealing with public concerns. Many voiced concerns that were dismissed as trivial and assurances were repeatedly issued that cane toads were benign (Meredith 1996). The failure to adequately respond to public fears may have laid the foundations for what was to follow.

In July 1935 cane toads were bred at the experimental station. From this spawning, 1,560,000 eggs were produced and 62,000 young cane toads were released into cane fields (Bell 1940). With the news of the provision of toads, cane farmers quickly requested toads for their cane fields, and toads were later provided for cane fields along the Queensland coast (Tyler 1976).

The liberation of cane toads throughout Queensland further fuelled public reaction. Various instances of cane toads being collected and killed were being reported. The cane industry responded by issuing further statements about the benefits of cane toads and asserted that they had "minimal undesirable effects" (Muntgomery 1936). Scientists from various agricultural stations throughout Queensland reported that toads were consuming cane beetles but were quite guarded in claiming that the war on cane beetles had been won. Other reports (e.g. Kinghorn 1938) indicated that cane toads were consuming a much wider variety of prey items than just cane beetles and that their inability to control cane beetles to produce economic gains was not occurring. Similar reports of the failure of toads to target economic pest species or control cane beetles were now being received from overseas cane plantations where toads had been introduced (e.g. Hawaii, Pemberton 1934; Puerto Rica, Wolcott 1937; Trinidad, Weber 1938; Philippines, Alcala 1957).

The public concern that toads were eating unintended prey ultimately forced the Commonwealth Government to act. In late 1935, the Commonwealth Department of Health issued a temporary ban on the further release of cane toads until this issue could be resolved. The toads that had been released, bred and the march of the cane toads had begun. The ban only remained in place until 1938 when it was removed because there was no compelling evidence that cane toads had "undesirable feeding habitats". Unfortunately, the first rigorous study of prey selection in cane toads was not carried out until 1962. This study (Hinckley 1962) showed that toads were quite indiscriminate in their feeding choices and were feeding upon beneficial prey species at the same rate as they were feeding on harmful pest species.

Public fears had not been quelled and cane toad killing was becoming a sport around the cane towns of Queensland. This activity became so prevalent that in 1938 the Queensland Government debated issuing of a decree that would make it illegal to kill or harm cane toads. The decree was not passed but public opinion was becoming strongly polarized about the virtues and vices of cane toads (Tyler 1976).

Up to this time, the Queensland sugar cane growers had relied on information that was provided by cane growers overseas (e.g. Dexter 1932). Reports from the Philippines and Hawaii had indicated that cane toads were quite successful in controlling cane beetles (Tyler 1976) but these reports were issued by those within the industry. No independent studies had been carried out. The first controlled study was undertaken in Hawaii in 1941 by Illingworth, and it was found that toads were impacting on a much wider range of non-target species than originally reported. This was later followed and endorsed by similar independent studies (e.g. Reimer 1959).

In Australia, a series of internal reports were prepared (Queensland Department of Primary Industries) that showed that toads were not as effective in the Queensland cane fields as predicted (Covacevic and Archer 1975). Very little attention was given to the impact of cane toads on vertebrate species.

Cane toads on the march

With the resumption of cane toad introductions in 1938, cane toads were imported into cane fields further south along the Queensland coast. The main areas where toads were released was the Cairns-Innisfail area and the Proserpine–Mackay region. In each of these areas, they prospered and spread. Soon cane toads were found many kilometers away from the cane growing areas and in the non–cane communities of Queensland (Tyler 1989).

Cane toad releases were now made in areas well away from Gordonvale and Innisfail in the far north of Queensland. They were transported south to cane growing areas south to Bundaberg. By the end of WW11, cane toads were well established along the Queensland coast but there had been little indication that the march of the cane toad would take them inland and well away from the cane fields where they were supposed to remain. In the 40 year period after their initial release, cane toads expanded their numbers and range with unsuspected haste. Sabath *et al.* (1981) calculated that toad populations increased in size and range in an exponential fashion so that by 1974 they occupied 33.8 % of the area of Queensland (i.e. 584,000 km^2). During this period of uncontrolled expansion of their range, cane toads increased their range annually by 8.1%.

In the late 1950s the first toads were found to the north of Brisbane and by the early 1960s the first Australian capital city was experiencing "cane toad mania". The first cane toads were greeted with annoyance and were generally ignored. However, the avalanche that followed could not be ignored and Brisbanites were outraged. It became a common experience to venture out into the suburban backyard and see several to many toads on the lawn. Toads often took shelter in, or under, houses by day and were frequently discovered under sheets of metal, old palings or other materials left lying around the yard. Television and newspaper articles featured stories that often referred to the discovery of toads in new areas as an "invasion". Television programs also often screened images of cane toads feeding at the dog or cat bowl at the back door of a house and sometimes they screened images of dead or dying dogs in the back yard. Warnings were issued to lock up your pet animal at night to protect it from a lethal experience with toads. The suburban peace of Brisbane was shattered (Tyler 1989).

The spread of cane toads continued unabated, despite the cessation of toad releases in the cane plantations. Toads were expanding their range rapidly of their own accord, although many were accidentally being shipped around the country. For example, in 1963 cane toads were found at Normanton on the Gulf of Carpentaria, at that time more than 500 kilometres from the nearest known toad population (Easteal 1981). These toads had most likely arrived as accidental stowaways in road shipments and escaped during unloading. This population was to continue to thrive and spread both east and west, linking up with the more coastal toad populations in the early 1970s, crossing the Northern Territory border in 1994 and forging on towards Darwin and Western Australia. Radio-tracking studies of toads in the Northern Territory has shown that the species can expand its range by up to 70 kilometres per year in the monsoonal areas of Australia (Salleh 2005). Recent movements of cane toads in the Northern Territory indicate that cane toads will reach the Western Australian border by 2010 (Seabrook and Dettman 1996).

Some 150 kilometres ahead of the Brisbane advance southward, cane toads first appeared at Byron Bay on the New South Wales north coast in 1966 (Van Beurden and Grigg 1980). These toads have continued radiating southwards but at a much slower rate than toads in Queensland, only reaching Yamba in 2004. Isolated populations have subsequently appeared on the New South Wales' north coast at Angourie, Brooms Head and Port Macquarie. Ormsby (1957) predicted that toads would be able to survive in temperate areas as far south as Sydney. To date, only one breeding population has become established in Sydney and that was eradicated within three months of its detection (FATS Frog Rescue data.).

Cane toads are regularly assisted in their spread by road and rail freight. The Frog and Tadpole Study Group of NSW conducts a Frog Rescue Program in greater Sydney. Between 1998-2005 over 200 toads were collected from Sydney (FATS Frog Rescue Service data).

In New South Wales, the movement of cane toads south along the coast is slow and efforts have been initiated to thwart further movement south. However, in 2004 toads were found in the higher parts of the New England District, at Glen Innes and Tenterfield, placing them within only a short distance from the headwaters of western flowing drainages.

Why are cane toads so successful at dispersing across the Australian landscape? Cane toads are a tropical species that originally inhabited montane and lowland rainforest in Southern and Central America (Strussman *et al.* 1984). How can they be so successful in a dry continent like Australia?

Although cane toads originate from tropical areas, many of these locations experience pronounced "dry" seasons. Toads have both physiological and behavioral traits to help them survive long periods without water. Several studies have been carried out to measure the ability of toads to survive desiccation (e.g. Ruibal 1962; Krakauer 1970; Walker and Whitford 1970). It was observed that toads can lose up to half of their body weight by desiccation and still survive. They are also able to reduce desiccation in dry environments by seeking cool areas and reducing the exposure of their body's evaporative surfaces (Krakauer 1970; Dobkin *et al.* 1989). In addition, toads are able to absorb water from the air or from damp soil through the belly skin (Bently and Main 1972). In dry conditions, water can also be stored in the bladder and returned to the bloodstream as needed (Ruibal 1962; Shoemaker and Waring 1968). Toads are also able to alter the osmotic pressure of their blood by controlling the reabsorption of urea from the bladder, and thus reduce water loss through the urine. This ability is hormonally controlled (Shoemaker and Waring 1968) and can keep a toad alive for many months in the absence of water. It also permits toads to survive in saline environments (Ely 1944). This has allowed toads that have taken shelter in shipping containers to survive for long periods without water and still be able to rapidly disperse when finally released.

Cane toads also have a great capacity for unassisted dispersal (Freeland and Martin 1985). In the 'dry' season, they tend to congregate around sites where water is present and most daily movements consist of traveling from the shelter site to the water point and back again (Carpenter and Gillingham 1987). In the 'wet' season, toads move between water holes, usually in straight lines, and so cover long distances quickly. They do not have a home range (Brattstrom 1962) and most movements by individual toads are small (average 16 meters per night, Schwarzkopf and Alford 1996). During the 'wet' season, movements up to 1 kilometer per night have been recorded. The lack of a home range means that toads are able to freely disperse (in all directions) when environmental conditions are suitable. In addition, juvenile toads rapidly disperse from the site where they were spawned and colonise new waterholes (Seebacher and Alford 1999). This increases the genetic diversity of toads at each site (Easteal and Floyd 1986; Sinsch 1997). Toads have the genetic capacity to respond to new environments quicker than most other amphibians (Savage 1960).

Cane toads are opportunistic in their foraging modes and consume a wide range of prey items (Strussman *et al.* 1984). This, combined with their ability to withstand body water loss; tolerate high and low environmental temperatures (Stuart 1957; Barton 1977; Beiswenger 1978; Floyd 1984); travel long distances; and aided by protective, foul-tasting and toxic body secretions, has meant that toads were relatively unrestricted in their ability to disperse across large areas of northern and eastern Australia.

Gauging the public reaction

The public reaction to cane toads has changed over the last 80 years. Initially, cane toads were regarded as a necessary, although an ugly and unbecoming tool of the cane farmer. Their rapid spread, coupled with the realization that their skin toxins were lethal to domestic (and native) animals, changed this attitude quickly. By the early 1960s cane toads were considered "noxious animals" in all states in the country (Tyler 1989).

The range of public attitudes to cane toads is perhaps best illustrated by the portrayal of toads in Australian film and literature. The documentary *Cane Toads: an Unnatural History*, produced by Lewis in 1988, depicted toads and the people who interacted with them in an arcane manner. The documentary correctly conveyed the polarization of opinions about toads while mocking the inconsistencies in public attitude and reactions to toads. *Toad Rage* (Gleitzman 1999) ridiculed the passion that people had adopted in punishing toads, while *Cane Toad: What Happened to Baz?* (Clayton and Silke 2003), a short film about the plight of a lost toad, further pilloried our toad paranoia.

An opportunity to gauge recent public reaction to cane toads was possible in 2000 in Sydney. The Frog and Tadpole Study Group (FATS), in collaboration with the NSW National Parks and Wildlife Service (NPWS), initiated a *Toad Awareness Program* for Sydney-siders. The program was stimulated by the collection of over 50 toads from greater Sydney the previous year (FATS Frog Rescue Service data). Brochures were prepared for distribution to fruit markets, produce wholesalers and other potential arrival destinations for stow-away toads.

For a two week period in 2000, radio and newsprint media urged Sydney residents to report suspected toads to a central contact number. Each report was followed up by an inspection of the location of the sighting and an interview with the person who made the report. Ninety two reports of cane toads were received during the fortnight and the identity of 82 observations was established (Table 1). Eight cane toads were correctly reported. The majority of the reports proved to be cases of misidentification of native frogs. One of the most disturbing aspects of this publicity campaign was that it fueled anxiety in the community and this, in turn, was probably responsible for the large number of sightings where the caller was sure that they had seen a toad, despite the animal not fitting any of the characteristics listed on the brochure. Even when confronted with the misidentified frog (or lizard), a common response was that it "had to be a toad" because toads were on the loose in Sydney.

In 2002, the Office of the Supervising Scientist in the Northern Territory prepared a report on the likely impact of toads on Kakadu National Park. The report indicated that initial declines in certain groups of native animals were likely, but highlighted the impact that toads would have on tourism and the indigenous people. The public perception associated with the arrival of toads in Kakadu was akin to one of the despoiling of a pristine wilderness (van Dam *et al.* 2002).

Table 1. Identity of "toads" reported in Sydney in March 2000

Species	Common Name	Number
Limnodynastes peroni	Striped Marsh Frog	33
Litoria peronii	Perons Tree Frog	14
Crinia signifera	Common Eastern Froglet	11
Limnodynastes dumerilii	Eastern Banjo Frog	9
Bufo marinus	Cane Toad	8
Litoria entate	Bleating Tree Frog	2
Litoria caerulea	Green Tree Frog	2
Heleioporus australiacus	Giant Burrowing Frog	2
Tiliqua scincoides	Eastern Blue-tongue Lizard	1

The uses of cane toads

Cane toads were initially introduced to control sugar cane beetles. While they certainly eat cane beetles, they proved to be unsuccessful at controlling beetle infestations in cane plantations and the use of them for this purpose was abandoned in the 1940s in favour of newly developed pesticides (Tyler 1989). As toads became more widespread and abundant, alternate uses were sought for these animals. The first commercial use of toads was for pregnancy testing (Bettinger and O'Loughlin 1950). Urine samples from the patient were injected into the lymph sacs of a toad. Three or more hours later, urine was collected from the toad and examined for evidence of spermatozoa. If spermatozoa were present, the pregnancy was confirmed. This technique was used widely in Australia from 1949 until 1963 when it was replaced by a chemical test. During the period of its use as a laboratory testing animal, toads were collected and held in most of the larger hospitals throughout Australia.

The robust nature of cane toads also made them ideal research animals. Toads were used in many research laboratories throughout Australia, particularly those investigating nerve-muscle interactions. It was also found to be a useful animal for the study of cardiac stimulants and depressants (Tyler 1989). They have also been used in gastric acid control studies (Taylor *et al.* 1985a,b) as well as for biochemical suppression studies (Otani *et al.* 1969).

The robustness of toads meant that they were an ideal teaching animal for live study and dissection. Universities, schools and colleges often had toad-holding facilities and received large shipments of toads prior to their use. While toads are still used for teaching purposes, this role has greatly decreased with the advent of alternate teaching aid, the establishment of Animal Ethics Committees and the difficulty in procuring large toads in Queensland.

In the 1970s, toad skins were harvested in Australia for tanning. A tanning factory was established in Nambour in Queensland and the tanned skins were fashioned into leather for making shoes, handbags and other accessories. This operation did not prosper and the factory closed in 1980. Other smaller scale tanning companies still operate but their merchandise is of a more arcane nature; handbags made from intact toads, toad statuettes, key rings or other unusual keepsakes are still made from cane toads (Figure 2).

Figure 2. Cane toad statuette and purse.

The drive to gain economic benefit from the large-scale use of cane toads has dwindled away, partly in response to a decline in toad numbers in areas where they had previously been abundant. Small-scale and novelty industries are likely to persist for some time to cater for the public's perverse sense of disaffection for cane toads (Woodford 1996).

Toads and the law

The first legislation affecting toads was an embargo enacted by the Commonwealth Government in 1938 that prevented the further deliberate release of cane toads into new areas of Australia, especially Queensland. The embargo was enacted because it was evident, after only three years, that toads were not remaining in the cane growing areas and were quickly invading new areas. The potential impacts of this invasion were being hotly debated, and the Federal Government decided that discretion was required until more information was available. The ban remained in place for only a few years, and was lifted in response to pressure from cane growers to have toads released into other parts of Queensland.

The deliberate introduction of cane toads into the cane growing areas of Queensland provided many more opportunities for toads to invade new landscapes. Toads began to appear in towns and cities across the country as a result of toads hitchhiking in consignments of produce and other materials. Following a number of well-publicised toad escapes and ongoing reports of toads in new areas, the various states in Australia began to tighten laws covering the movements of toads across borders. New South Wales and Western Australia were the first two states to enact legislation in 1953, the other states followed thereafter. Under current law, permits are required to import cane toads and the conditions for holding and transporting the toads are quite stringent. But these rules and regulation did little to prevent the spread of toads. Toads first arrived in New South Wales in 1966 (Van Beurden and Grigg 1980), not by crossing the Queensland border, but as a result of accidental importation with produce and goods from Queensland. In 1963, an isolated population of toads was discovered near Normanton, in north-western Queensland (Easteal *et al.* 1985).

The shipping and transport of toads around Australia for commercial purposes was also not without risk. In 1974, twenty toads imported for school dissection escaped from a high school in Darwin. This triggered the first toad alert for Darwin. Volunteers undertook to search for and collect the toads. Wanted posters were issued (Figure 3) and eventually the toads were caught. In the same year, a crate containing a consignment of toads was inadvertently broken open at Perth airport and 50 toads escaped. A concerted public campaign was mounted and 49 toads were eventually re-caught. This campaign was costly and further reinforced the general alarm that was building in the community.

Cane toads have never been listed under Commonwealth legislation as a noxious animal or pest species. Although they were listed as noxious animals by Queensland and the Northern Territory Governments but in 1999

Figure 3. Wanted poster, Darwin 1974.

Queensland removed toads from the "Declared Animal" list (administered by the Department of Natural Resources).

The first legislation that related to the environmental impacts of cane toads did not appear until 2004. Cane toads have been listed as a Key Threatening Process under the *Threatened Species Conservation Act 1995* in New South Wales. This listing was made because cane toads are recognized to have an adverse impact on native fauna (such as frogs), especially those already in low abundance. The listing obliges all subsequent development options to consider its potential to introduce, spread or alter the abundance of toads in an area and to develop ameliorative measures to counteract any potential impacts on native fauna.

The environmental impacts of cane toads

Three environmental impacts are attributed to cane toads: competition with native species for resources (especially prey items), killing of native predators and scavengers through the ingestion of skin toxins, tadpoles or eggs, and the indirect killing or suppression of native aquatic animals by water-borne skin secretions.

Competition with Native Species

There have been several studies that have examined the diet of cane toads in Australia (e.g. Muntgomery 1936; Alexander 1965; Stammer 1981; Freeland *et al*. 1986; Catling *et al*. 1999) and overseas (Wolcott 1937; Weber 1938; Bailey 1976; Strussman *et al*. 1984; Evans and Lampo 1996). Early studies focused on checking the efficiency of toads to control sugar cane beetles and other economic pests (e.g. Dexter 1932; Bell 1940; Pippet 1975). These studies found that toads fed voraciously whenever prey items were available, especially on greyback beetles (*Rhabdocnemis obscura*) and army worms (*Spodoptera exempta*: Bell 1940). Various other invertebrates were consumed but little effort was made to determine if toads fed selectively. Pippet (1975) was unable to find evidence of selectivity and concluded that toads were indiscriminate feeders of a wide range of small, terrestrial prey items. The only selectivity that was inferred was that of prey size, with all prey items small enough to be eaten being targeted by the toads. Alford and Wilbur (1985) found that some competition did occur between *Bufo* and at least one other frog group (*Rana*) but the extent of competition was greatly affected by the original occupancy of a site. Unlike other frogs, cane toads will consume non-moving prey and it has been proposed that toads use olfaction, as well as vision, to determine food items (Rossi 1983).

Apart for feeding upon a wide range of prey items, toads have also been shown to be voracious feeders. Freeland *et al*. (1986) measured the predation rates of toads compared with a native frog species (*Litoria pallida*). Cane toads were found to consume on average 200 prey items each night whereas the Pale frog could only manage six prey items per night. Cane toads grow to be many times larger than most native frogs and so the range and biomass of consumed prey increases quickly as the toads grow. Their ability to feed and grow quickly means that they can have a dramatic impact on the available food resources in an area. If prey items are concentrated, toads will opportunistically feed and deplete food resources before native species are able to forage. This ability created considerable distress for bee-keepers when it was found that toads will congregate around hives and gorge themselves on bees night after night (Lever 1944).

In a study of frogs and toads in northern New South Wales, Van Burden (1980) found that native frogs could coexist with toads while toads were in low density, however, as toad numbers increased, competition (for food and through predation) shifted the balance in favour of toads. In contrast, Zug *et al*. (1975), in a study in southern New Guinea were not able to find evidence of competition between toads and native frogs and reptiles. This study is not directly comparable to others as Zug *et al*. (1975) worked in areas where the native fauna had already been disturbed through agriculture or timber getting. When more natural areas were included in the study sites (Zug and Zug 1979), competition for food resources was noted, but because of the abundance of food resources in these areas, competition had little impact on native species.

Freeland and Kerin (1988), in a study conducted in the Northern Territory, were also unable to find a long-term impact of cane toads on the native fauna, including frogs and their food sources. In another study conducted in the Northern Territory, Catling *et al*. (1999) found an adverse impact on three native taxa (dingo, beetles, and one frog species *Litoria rothii*) but they were unsure of the mechanism of the impact or its longevity. It is known, however, that cane toads will eat native frogs (Freeland *et al*. 1986).

Killing of native predators and scavengers

Cane toads are not agile animals and cannot easily flee from would-be predators. The toad's standard method of defense against predators is to bloat itself into as large a size as it can, making itself appear large and less edible. However, if the predator grapples with the toad and places the toad in its mouth, secretions are released in another line of defense. Toads have a number of skin secretions that are unpleasant tasting and irritating to exposed skin surfaces. In addition, they have a pair of parotoid glands located on either side of the neck and the secretions from these glands are toxic to a wide range of animals (Breeden 1963, Covacevich and Archer 1975; Pippet 1975; Van Beurden 1980; Stammer 1981; Shine and Covacevich 1983; Burnett 1997; Crossland 1997). To date, 14 compounds have been identified in toad skin secretions and these substances affect heart contractions, interfere with the central nervous system and can cause vomiting, salivation or paralysis (Allen and Neill 1956; Tyler 1989; Akizawa *et al*. 1994).

Covacevich and Archer (1975) first investigated the range of predators being killed by toads by distributing a questionnaire amongst researchers, veterinarians, schools and other associated potential interest groups. They found that a wide range of reptiles were affected (notably frog-eating snakes and goannas), wading and hunting birds, quolls and Tasmanian devils. This list has been considerably expanded since then and Table 2 summarises the range of native species known to have been killed by cane toads in Australia.

The efficacy of the toxins produced by toads has been investigated to determine if Australian native animals are likely to adapt and co-exist with toads. In studies carried out in Brazil, where toads are native, tadpoles from local species were found to be able to eat toad tadpoles without succumbing to their toxin (Crossland and Azevedo-Ramos 1999). Australian tadpoles are not so fortunate; many die from exposure to toad eggs and tadpoles (Crossland and Alford 1998). It is not known if the Brazilian tadpoles survived because previous exposure to the toxins had reduced their sensitivity, or if there has been an evolutionary response leading to immunity to the toxins. Tadpole susceptibility to toad toxin varies depending on the size and species of the tadpole (Crossland 1998).

Table 2: Species killed by cane toads

Taxa	Species	Reference
Mammals	*Dasyurus sp.*	Pippet 1975
	Dasyurus geoffroii	Archer and Covacevich 1975
	Sacrophilus harrissii	Archer and Covacevich 1975
	Canis lupis familiaris	Knowles 1964
	Homo sapiens	Rabor 1952
Reptiles*	*Varanus gouldii*	Stammer 1981
	Varanus timorensis	Burnett 1997.
	Varanus panoptes	(W. Freeland in Tyler 1989)
	Varanus varius	Van Beurden 1980
	Varanus mertensis	White 2003
	Varanus mitchelli	White 2003.
	Crocodylus johnstoni	White 2003
	Acanthurus antarcticus	Covacevic and Archer 1975; Shine and Covacevic 1983
	Boiga irregularis	Covacevic and Archer 1975
	Dendrelaphis punctulatus	Phillips and Shine 2004
	Liasis olivaceus	White 2003
	Notechis scutatus	Covacevic and Archer 1975
	Pseudechis australis	Shine and Covacevic 1983
	Pseudechis papuanis	Pippet 1975
	Pseudechis porphyriacus	Covacevic 1974, Shine and Covacevic 1983
	Pseudonaja textilis	Covacevic and Archer 1975, Shine and Covacevic 1983
	Stegonotus cucullatrus	Covacevic and Archer 1975
	Egernia bungana	Covacevic and Archer 1975
Birds	*Corvus sp.*	Covacevic and Archer 1975
	Dacelo novaeguineae	Covacevic and Archer 1975
	Dupetor flavicollis	Van Beurden 1980
	Ixobrychus minutus	Van Beurden 1980
Frogs	*Cyclorana novaehollandiae*	Alford *et al.* 1995
	Limnodynastes ornatus	Alford *et al.* 1995,Crossland 1998
	Litoria alboguttata	Crossland 1998
	Litoria bicolor	Alford *et al.* 1995
	Litoria infrafrenata	Alford *et al.* 1995
	Litoria nigrafrenata	Alford *et al.* 1995
	Litoria rubella	Alford *et al.* 1995

*Phillips *et al.* (2003) calculated that at least 49 taxa of Australian snakes were at risk to cane toad toxin with most unable to deal with likely doses.

Various native animals have shown an ability to either withstand toad toxins (e.g. the freshwater snake *Tropidonophis mairii*, Phillips and Shine 2004; Kreffts river turtle *Emydura kreffti* and the saw-shelled turtle *Elseya latisternum*, Alford *et al*. 1995; various water birds including herons, cranes, swamp hens, Covacevic and Archer 1975; ibis, Goodacre 1947; kites, pheasants and tawny frogmouths, Freeland 1985), or have learned to only consume the non-toxic parts of the toad's body (e.g. black rats, Adams 1967; water rats, Covacevic and Archer 1975; crows and currawongs, Alford *et al*. 1995).

Water-borne effects

Cane toads can also impact on native animals by standing or swimming in water. The "wash" that is released from adult toads and from their eggs can be toxic or disruptive to aquatic animals (Hearden 1991). Tadpoles of some native frogs are killed if they eat toad eggs (Crossland and Alford 1998), or they may be killed through exposure to water-soluble proteins released by toad eggs or by adult toads that have frequented the pond. It has also been recorded that some toads employ spawn proteins to retard tadpole growth in competing frog species (Banks and Beebee 1987).

The battle to control the spread of cane toads

Toads were released in Queensland in 1935 and in the same year the Commonwealth Government imposed a ban on the further release of cane toads. Cane toads quickly demonstrated an ability to feed on food sources other than cane beetles and to inhabit areas other than cane fields. The realization that toads were expanding their range beyond cane growing areas was alarming for a very wary public and the first toad "round-ups" were carried out in the areas outside of Gordonvale and Tully in 1936 and 1937. Despite the concern, the Federal Government ban was lifted in 1936 to pave the way for further toad releases in Queensland.

Public anxiety about cane toads increased as cane toads proved to be an unstoppable foe. In some areas, local governments sponsored the collection of toads, and often a small bounty was given for toads collected and taken to the receiving station. These types of sponsored collections still occur (e.g. Darwin, Murwillimbah). Anecdotal reports suggest that the killing of toads became increasingly widespread. Toads were either collected and humanely killed, or they were indiscriminately sought out and smashed with sticks, metal bars, golf clubs or other weapons, impaled with spears or iron rods, poisoned with household chemicals, decapitated or simply run over by vehicles. The killing of toads in northern Australia has become folklore, and many tales are told of the hundreds of toads that have been killed by the most bizarre and outlandish methods imaginable. Despite, this frenzy of attacks by the public, toads continued their relentless march across the landscape (Meredith 1996).

The need for the strategic control of cane toads was first postulated by Froggatt in 1936. However, from this time until 1988, no efforts were undertaken to seek out a practical method of control although various suggestions were made. For example, Waterhouse (1974) suggested using carnivorous beetles to kill toads. Various other native predators were searched for and reported on (e.g. dung beetles, Waterhouse 1974; yabbies, Hutchings 1979; birds, Cassels 1970; freshwater snakes, Covacevich and Archer 1975; turtles, Gunn *et al.* 1972). Van Beurden (1980) demonstrated that *Mimomyia* mosquitoes fed on cane toads, supporting the proposal that mosquito-borne diseases could be used to control toads. The arguments for control mounted, and in 1985 Freeland presented the first cogent and well-supported argument for toad control in Australia.

In 1984, a meeting was held in Brisbane comprising state and federal wildlife agencies to consider the options for toad control. Arising from this meeting, the Federal Government directed the CSIRO to initiate a research program aimed at controlling cane toads. One important priority of this program was to protect important wetlands, such as in Kakudu National Park, from the threatened invasion of toads. $1.25M from the Commonwealth Government and $90,000 from state governments was provided over three years and work began in 1990. In 1993, the Federal Government provided a further $2M but finding ceased in 1997.

Various projects had been carried out under this funding. The major one was the search for a toad-specific pathogen that could be used in the widespread control of toads (Speare and O'Shea 1989). The project identified several potential pathogens, but none were successfully developed or tested. In 2005, a press release claimed that the Animal Health Laboratory in Geelong was trialing a modified virus that had the potential to exterminate toads in Australia (Robinson 2005).

Cane toad musters

Local and regional initiatives have also been used to try to impede the spread of toads. Often these have involved the physical collection of toads from an area. There are various accounts of small towns and community-organised toad hunts. Some of these hunts have been well controlled (e.g. Murwillimbah in New South Wales, Reid 2000) and efforts taken to prevent cruelty to the toads and reduce the death of native amphibians mistaken for toads. The majority of other efforts have been less well organized and toad hunters have been left to their own devices. There have been no records kept of the numbers of toads, or other frogs, collected.

Organised toad musters have been conducted in several towns. Most notably Port Macquarie in New South Wales. Port Macquarie lies some 250 kilometres south of the nearest toad infestations. In 1995, toads were reported to the local Council, and in 1996 twelve large toads were collected by residents and brought in for identification. Over the next few years, toads increased in numbers and there were grave fears that Port Macquarie could become a regional radiation centre for toads in New South Wales. In 1998, the local council and the Department of Environment and Conservation (then the National Parks and Wildlife Service) organised the first "Toad Muster". A media campaign informed residents that they were to be on the look out for toads, and if any were seen, they were to be collected and brought to a central depot. No rewards were offered. The initial response was overwhelming and a large contingent of the town took part in the muster. Over 400 toads were collected during the weeks of the muster and it was so successful that it became an annual event until the toads ran out.

Musters in the Port Macquarie area have continued to be held each year and the results have been surprising (Table 3). Large numbers of people again took part in the musters over the next three years but toad captures were falling. With the low number of toads being seen and caught, public interest in the musters waned. Musters were still conducted each year but the public participation was now quite low.

When the Port Macquarie toad musters were initiated, it was hoped that the spread of toads could be lessened by the collection of toads. Alarming reports had been noted about the high fecundity of toads and their ability to disperse quickly over large distances in northern Australia (Seabrook and Dettman 1996). It was never anticipated that the musters could eradicate toads from the area. While the most recent muster results suggest that toad

Table 3. Toad numbers reported from Toad Musters at Port Macquarie (1997-2005).

Year	Number of toads captured	Size range of toads captured (Snout-vent Length) cm	Estimate of number of people involved in Muster
1997	440	4-26	500+
1998	280	5-25	500+
1999	55	5-27	500+
2000	20	5-20	300
2001	19	4-16	100
2002	4	4-17	50
2003	11	3-15	50
2004	3	4-10	10
2005	0	-	20

numbers have been greatly reduced, authorities at Port Macquarie are geared up for another muster in February 2006 (February has been the month when most toad sightings are made at Port Macquarie).

If toads have been eliminated from the Port Macquarie area, it will be the first case of an eradication of an established population of toads in Australia. Several factors may have been responsible for this outcome. Firstly, based on anecdotal information, it appears that survivorship of juvenile toads is much lower at Port Macquarie than for northern Australia. Secondly, most of the toads that were collected were taken from roadside areas. It is now known that the largest toads frequent roads (Seabrook and Dettman 1996) and clearings and the musters may have been selectively removing the larger animals from the population. Thirdly, in 2002 and 2003, Port Macquarie suffered a record drought. Many areas where frogs were regularly found breeding were dry (T. Aaso pers.comm.). With toad numbers depressed, breeding conditions poor and the larger animals being selectively removed from the population, it is possible that entire cohorts are missing from the population. If toads still remain in the area, they will be removed when found, and the population will not be given the opportunity to recover.

The Port Macquarie case suggests that the dispersal of toads in more temperate areas can be halted (see Van Buerden 1981 and Sutherherst *et al.* 1996 for a discussion of the bioclimatic limits of toad dispersal in Australia). It has also fuelled the instigation of toad musters at the next two southernmost outliers of toad distribution in New South Wales (Brooms Head and Angourie). It is planned that musters will be followed up by "hit squads" of trained volunteers who will thoroughly search areas where cane toads have been sighted.

Toad musters may only be effective in temperate areas where the opportunities for toad breeding are abbreviated and the human population density is high enough to enable thorough searching of areas. Northern Australia does not have these circumstances and so other means must be employed to slow down the spread of toads. Activists in Western Australia have mobilized to try to prevent toads from crossing the Northern Territory - Western Australian border (http://stopthetoads.com).

In 2005, the Northern Territory Government offered a prize for the best toad trap devised. The winning entry, designed by Paul Baker, has proven so successful that it is now being marketed (Figure 4). The trap utilizes a near-ground light source to attract insects into the metal cage trap. Gates of interleaved plastic are positioned in the walls of the trap and the gates can only be opened by an animal leaning on them and pushing them apart. This behaviour is used by toads in the pursuit of prey but does not appear to be part of the foraging strategy of native amphibians. The traps offer a means to collect large numbers of toads from an area in a cost effective manner. Whether they can slow down or stop the spread of toads in northern Australia remains to be seen.

The new toad on the block

In April 2003, Australian Quarantine and Inspection Service (AQIS) officials at Perth impounded three toads from a shipping container carrying mining equipment that had recently returned from mine sites in Irian Jaya. The toads, initially believed to be cane toads, were collected and killed. Further checking revealed that the toads were Asian black-spined toad *Bufo melanostictus*. Six months later, another shipping container with mining equipment, that had been used in Indonesia, was inspected at Cairns. Again, toads were found and once more they were black-spined toads. In 2004, black-spined toads were also found in a shipping container in Sydney (FATS Frog Rescue data).

Since the discovery of these toads, identification circulars have been prepared for AQIS inspectors at Australian ports. However, it remains probable that black-spined toads have already been imported into Australia and not detected or not recognized as being different to cane toads. The volume of shipping between Australia and Asian ports makes it highly likely that black-spined toads will continue to be accidentally imported into this country. These toads are highly fecund and share many of the ecological of traits cane toads (Inger and Stuebing 2005). How will these toads be greeted by Australians? Unlike cane toads, the black-spined toads were not brought in to save an industry. These are truly uninvited guests who may yet follow a path already paved by their *Bufo* cousins.

Figure 4. Commercially produced cane toad trap.

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References

Adams, N.G. 1967. *Bufo marinus* eaten by *Rattus rattus*. *North Queensland Naturalist* 34:5.

Akizawa,T., Mukai, T., Matsukawa, M., Yoshioka., M, Morris, J.F. and Butler, V.P. 1994. Structure of novel bufadienolides in the eggs of a toad, *Bufo marinus*. *Chemical Pharmacology Bulletin* 42:754-756.

Alcala, A.C. 1957. Phillipine notes on the ecology of the giant marine toad. *Silliman Journal* 4:90-96.

Alexander, T.R. 1965. Observations of the feeding behaviour of *Bufo marinus* (Linne). *Herpetologica* 20(4): 255-259.

Alford, R.A. and Wilbur, H.M. 1985. Priority effects in experimental pond communities: competition between *Bufo* and *Rana*. *Ecology* 66:1097-1105.

Alford, R.A., Cohen, M.P., Crossland, M.R., Hearnden, M.N. and Schwarzkopf, L. 1995. Population biology of *Bufo marinus* in Northern Australia. Pp. 173-181 in *Wetland Research in the Wet-Dry Tropics of Australia* edited by C.M. Finlayson, Supervising Scientist Report No. 101, Office of the Supervising Scientist, Canberra.

Allen, E.R. and Neill, W.T. 1956. Effects of marine toad toxins on man. *Herpetologica* 12(2): 150-151.

Altman, J., Griffiths, T. and Whitehead, P. 2003. Invasion of the rubbish frog. *Australian Nature* 2003: 44-51.

Bailey, P. 1976. Food of the marine toad, *Bufo marinus*, and six species of skink in a cacao plantation in New Britain, Papua New Guinea. *Australian Wildlife Research* 3:185-188.

Banks, B. and Beebee, T.J.C. 1987. Spawn predation and larval growth inhibition as mechanisms for niche separation in amphibians. *Oecologica* 72:569-573.

Barton, K.E. 1977. Behavioural thermoregulation in the toad

Bufo marinus in a temperature gradient. *Bulletin of the New Jersey Academy of Science* 22: 48-50.

Beiswenger, R.E. 1978. Response of *Bufo* tadpoles (Amphibia: Anura: Bufonidae) to laboratory gradients of temperature. *Journal of Herpetology* 12:499-504.

Bell, A.F. 1940. The giant toad in Queensland Australia. *Agricultural Journal* (*Fiji*) 11(2): 55.

Bently, P.J. and Main, A.R. 1972. Zonal differences in permeability of the skin of some anuran amphibians. *American Journal of Physiology* 223:361-363.

Bettinger, H.F. and O'Loughlin, I. 1950. The use of the male toad, *Bufo marinus*, for pregnancy tests. *Medical Journal of Australia* July 8 1950: 40-42.

Boice, R and Boice, C. 1971. Interspecific competition in captive *Bufo americanus* toads. *Journal of Biological Psych*ology 12: 32-36.

Brattstrom. B.H. 1962. Homing in the giant toad, *Bufo marinus*. *Herpetologica* 18: 176-180.

Breeden, K. 1963. Cane Toad. *Wildlife Australia* 1:31.

Burnett, S. 1997. Colonizing cane toads cause population declines in native predators: reliable anecdotal information and management implications. *Pacific Conservation Biology* 3:65-72.

Carpenter, C.C. and Gillingham, J.C.1987. Water hole fidelity in the marine toad, *Bufo marinus*. *Journal of Herpetology* 21:158-161.

Cassels, M. (1970). Another predator of the Cane Toad. *North Queensland Naturalist* 37(151): 6.

Catling, P.C., Hertog, A., Burt, R.J., Wombey, J.C. and Forrester, R.I. 1999. The short-term effect of cane toads (*Bufo marinus*) on native fauna in the Gulf Country of the Northern Territory. *Wildlife Research* 26:161-185.

Clayton, D., and Silke, A. 2003. *Cane Toad. What happened to Baz?* Independent Film. WWW.cane-toad.com.

Cohen. M.P. and Alford, R.A. 1996. Factors affecting diurnal shelter site use by the cane toad, *Bufo marinus*. *Herpetologica* 52: 172-181.

Covacevich, J. 1974.An unusual aggregation of snakes following major flooding in the Ipswich-Brisbane area, south-eastern Queensland. *Herpetofauna* 7:21-24.

Covacevich, J and Archer, M. 1975. The distribution of the Cane Toad, *Bufo marinus*, in Australia and its effects on indigenous vertebrates. *Memoirs of the Queensland Museum* 17(2): 305-310.

Crossland, M.R. 1997. *Impact of eggs, hatchlings and tadpoles of the introduced cane toad Bufo marinus (Anura:Bufonidae) on native aquatic fauna in northern Queensland*. Unpublished PhD thesis, James Cook University of Northern Queensland, Townsville.

Crossland, M.R. 1998. Predation by tadpoles on toxic toad eggs: the effect of tadpole size on predation success and tadpole survival. *Journal of Herpetology* 32:443-446.

Crossland, M.R. and Alford, R.A. 1998. Evaluation of the toxicity of eggs, hatchlings and tadpoles of the introduced toad *Bufo marinus* (Anura: Bufonidae) on native Australian aquatic predators. *Australian Journal of Ecology* 23:129-137.

Crossland, M.R. and Azevedo-Ramos, C. 1999. Effects of *Bufo* (Anura:Bufonidae) toxins on tadpoles from native and exotic *Bufo* habitats. *Herpetologica* 1999:192-199.

Dexter, R.R. 1932. The food habitats of the imported toad *Bufo marinus* in the sugar cane sections of Puerto Rico. *Bulletin of the International Society for Sugar Cane Technology* 74: 1-6.

Dobkin, D.S., Gettinger, R.D. and O'Connor, M.P. 1989. Importance of retreat sites for the hydration state in *Bufo marinus* during a dry rainy season. *American Journal of Zoology* 29:88A.

Easteal, S. 1981. The history of introduction of *Bufo marinus* (Amphibia: Anura); a natural experiment in evolution. *Biological Journal of the Linnean Society* 16: 93 – 113.

Easteal, S., Van Beurden, E.K. Floyd, R.B. and Sabath, M.D. 1985. Continuing geographical spread of *Bufo marinus* in Australia: range expansion between 1974 and 1980. *Journal of Herpetology*. 19(2): 185-188.

Easteal, S., and Floyd, R.B. 1986. The ecological genetics of introduced populations of the giant toad, *Bufo marinus*: dispersal and neighbourhood size. *Biological Journal of the Linnean Society* 27:17-45.

Ely, C.A. 1944. Development of *Bufo marinus* larvae in dilute sea water. *Copeia* 1956(4): 256.

Evans, M., and Lampo, M. 1996. Diet of *Bufo marinus* in Venezuela. *Journal of Herpetology* 30:73-76.

Floyd, R.B. 1984. Variations in temperature preference with stage of development of *Bufo marinus* larva. *Journal of Herpetology* 18:153-158.

Freeland, W.J. 1985. The need to control cane toads. *Search* 16(7-8): 211-215.

Freeland, W.J. and Martin, K.C. 1985. The rate of expansion by *Bufo marinus* in northern Australia. *Australian Wildlife Research* 12: 555-559.

Freeland, W.J. 1986. Populations of cane toads, *Bufo marinus*, in relation to the since colonization. *Australian Wildlife Research* 13:321-329.

Freeland, W.J., Delvinqueir, B.L.J. and Bonnin, B. 1986. Food and parasitism of the cane toad *Bufo marinus* in relation to time since colonization. *Australian Wildlife Research* 13:489-499.

Freeland, W.J. and Kerin, S.H. 1988. Within-habitat relationships between invading *Bufo marinus* and Australian species of frog during the tropical dry season. *Australian Wildlife Research* 115:293-306.

Froggatt, W.W. 1936. The introduction of the great Mexican toad *Bufo marinus* into Australia. *Australian Nature* 9: 163-164.

Gleitzmann, M. 1999. *Toad Rage*. Pan MacMillan, Sydney.

Goodacre. W.A. 1947. The giant toad (*Bufo marinus*) an enemy of bees. *Aricultural Gazette of NSW* 58: 374-375.

Gunn, R.H., Galloway, R.W., Walker, J., Nix, H.A., McAlpine, J.R. and Richardson, D.P. 1972. *Shoalwater Bay area, Queensland*. Technical memo 72/10 CSIRO Division of Land Research, Canberra.

Hearnden, M.N. 1991. *Reproductive and larval ecology of* Bufo marinus (*Anura:Bufonidae)*. Unpublished Ph. D Thesis. James Cook University of Northern Queensland, Townsville.

Hinckley, A.D. 1962. Diet of the giant toad, *Bufo marinus* (L.), in Fiji. *Herpetologica* 6:410-411.

Hutchings. R.W. 1979. A native predator of the cane toad (*Bufo marinus*). *North Queensland Naturalist* 45(174): 4-5.

Illingworth, J.F. 1941. Feeding habits of *Bufo marinus*. *Proceedings of the Hawaiian Entomological Society* 11:51.

Inger, R.F., and Stuebing, R.B. 2005. *A Field Guide to the Frogs of Borneo*, (2nd Edition). Natural History Publications (Borneo), Kota Kinabalu.

Kinghorn, J.R. 1938. The giant toad *Bufo marinus* in Australia. *Australian Museum Magazine* 6:410-411.

Knowles, R.P. 1964. The poison toad and the canine. *Veterinary Medicine* 59:38-42.

Krakauer, T. 1968. The ecology of the neotropical toad *Bufo marinus* in south Florida. *Herpetologica* 24: 214-221.

Krakauer, T. 1970. Tolerance limits of the toad, *Bufo marinus*, in South Florida. *Comp. Biochemical Physiology* 33: 15-26.

Leonard, M.D. 1933. Notes on the food of the giant toad *Bufo marinus* (L.) in Puerto Rica. *Journal of Economic Entomology* 26: 11-12.

Lever, R.J.A.W. 1938. The giant toad – distribution, diet and development. *Agricultural Journal* (*Fiji*). 9(2): 28.

Lever, R.J.A.W. 1944. Food of the Giant Toad. *Agricultural Journal* (*Fiji*).15(1): 28.

Lewis, M. 1988. *Cane Toads. An unnatural History*. Film, IMDB Promotions. Film Australia Pty Ltd. Distributed by Umbrella Entertainments Australia.

Marchal-Segault, D. 1976. Toxicite de quelques insecticides pour des entate de *Bufo marinus* (Amphibiens, Anoures). *Bulletin of Ecology* 7: 411 – 416.

Meredith,P. 1996. Some truths about cane toads. *Australian Geographic* 44:84-99.

Muntgomery, R.W. 1935. The great American toad (*Bufo marinus*). *Cane Growers Quarterly Bulletin* 3:21-27.

Muntgomery, R.W. 1936. A survey of the feeding habits of the giant toad (*Bufo marinus*) and notes on its progress since introduction to Queensland. *Proceedings of the Queensland Society of Sugar Cane Technologists* 1936:63-74.

Ormsby. A.I. 1957. Notes on the giant toad (*Bufo marinus*). *Proceedings of the Royal Zoological Society of NSW* 1955-1956: 54-55.

Otani, A., Palumbo, N. and Read, G. 1969. Pharmacodynamics and treatment of mammals poisoned by *Bufo marinus* toxin. *American Journal of Veterinary Research* 30: 1865-1872.

Pemberton, C.E. 1933. Introduction to Hawaii of the tropical American Toad *Bufo marinus*. *Hawaiian Planters' Record* 37: 15-16.

Pemberton. C.E. 1934. Local investigations on the introduced tropical American Toad *Bufo marinus*. *Hawaiian Planter's Record* 38:186-192.

Pemberton, C.E. 1949. Longevity of the tropical American Toad, *Bufo marinus*. *Science* 110: 512.

Petranka, J.W. 1989. Response of toad tadpoles to conflicting chemical stimuli: predator avoidance versus "optimal" foraging. *Herpetologica* 45:283-292.

Phillips, B.L., Brown, G.P. and Shine, R. 2003. Assessing the potential impact of Cane Toads on Australian snakes. *Conservation Biology* 17:1738-1747.

Phillips, B.L. and Shine, R. 2004. Adapting to an invasive species: toxic cane toads induce morphological change in Australian snakes. *Proceedings of the National Academy of Science USA* 101:17150-17155.

Pippet, J.R. 1975. The Marine Toad, *Bufo marinus*, in Papua New Guinea. *Papua New Guinea Agricultural Journal* 26(1): 23-30.

Rabor, D.S. 1952. Preliminary notes on the giant toad, *Bufo marinus*. (Linn.), in the Phillippine Islands. *Copeia* 1952: 281-282.

Reid, J. 2000. *Cane Toad Community Education and Awareness Program, Northern Rivers Region*. National Parks and Wildlife Service, New South Wales.

Reimer, W.J. 1959. Giant Toads of Florida. *Journal of the Florida Academy of Science* 21: 207-211.

Robinson, P. 2005. Scientists onto the cane toad. *Age* 17 October 2005. Pp. 5.

Rossi, J.V. 1983. The use of olefactory cues in *Bufo marinus*. *Journal of Herpetology* 17:72-73.

Ruibal, R. 1962. The adaptive value of bladder-water in the toad *Bufo cogitatus*. *Physiological Zoology* 35:218-223.

Sabath, M.D., Broughton, W.C. and Eastel, S. 1981. Expansion of the range of the introduced toad *Bufo marinus* in Australia from 1935 to 1974. *Copeia* 1981(3): 676 680.

Salleh, A. 2005. Cane toads take the fast lane, literally. *News in Science*. 15 September 2005. http://abc.net.au/entate/new/stories/s1460974.htm

Savage, J. 1960. Geographic variation in the toad *Bufo marinus*. *Copeia* 1960:233-236.

Seabrook, W.A. and E.B. Dettman. 1996. Roads as activity corridors for Cane Toads in Australia. *Australian Journal of Wildlife Management*. 60:363-368.

Schwarzkopf, L. and Alford, R.A. 1996. Dessication and shelter site use in a tropical amphibian: comparing toads with physical models. *Functional Ecology* 10:193-200.

Seebacher, F. and Alford, R.A. 1999. Movement and microhabitat use of a terrestrial amphibian (*Bufo marinus*) on a tropical island: seasonal variation and environmental correlates. *Journal of Herpetology* 33:208-214.

Shine, R. and Covacevich, J. 1983. Ecology of highly venomous snakes of the Australian genus *Oxyuranus*. *Journal of Herpetology* 17:60-69.

Shoemaker.V.H. and Waring, H. 1968. Effect of hypothalamic lesions on the water balance response of the toad (*Bufo marinus*). *Comparative Biochemistry Physiology* 24:47-54.

Sinsch, U. 1997. Postmetamorphic dispersal and recruitment of first breeders in a *Bufo calamita* metapopulation. *Oecologica* 112:42-47.

Smyth, E.G. 1916. The white grubs injuring sugar cane in Puerto Rico. *Puerto Rico University Journal of Agriculture* 1: 141-169.

Speare, R., and O'Shea, P. 1989. The marine toad *Bufo marinus* and the search for a killer disease. Pp. 166-172 in *Proceedings of the American Association of Zoo Veterinarians Annual Meeting 14-19 October 1989,* edited by J.H. Olsen and M. Eisenacher. American Association of Zoo Veterinarians, Greensboro, N.C. Philadelphia.

Stammer, D. 1981. Some notes on the cane toad (*Bufo marinus*). *Australian Journal of Herpetology* 1(2): 61.

Stopthetoad.com. Conservation Council of Western Australia, Perth.

Straughan, I.R. 1966. The natural history of the cane toad in Queensland. *Australian Natural History* 15: 230-232.

Strussman, S., Ribeiro do Vale, M.B., Hoffmeister, M.H. and Magnusson, W.E. 1984. Diet and foraging mode of *Bufo marinus* and *Leptodactylus occelatus*. *Journal of Herpetology* 18: 138-146.

Stuart, L.C. 1951. The distributional implications of temperature tolerances and haemoglobin values in the toads *Bufo marinus* (Linnaeus) and *Bufo bocourti* Brocchi. *Copeia* 1951(3): 220-228.

Sutherherst, R.W., Floyd, R.B., and Maywald, G.F. 1996. The potential distribution of the cane toad, *Bufo marinus* L., in Australia. *Conservation Biology* 10:294-299.

Taylor, P.M., Tyler, M.J. and Shearman, D.J.C. 1985a. Gastric acid secretion in the toad *Bufo marinus* with the description of a new technique for in vivo monitoring. *Comparitive Biochemistry Physiology* 81A(2): 325-327.

Taylor, P.M., Tyler, M.J. and Shearman, D.J.C. 1985b. Gastric emptying and intestinal transit in *Bufo marinus* and the action of E prostaglandins. *Australian Journal of Experimental Biology and Medical Science* 63: 223-230.

Thomas, P. 1934. Cane toads save sugar crop. *Nature* 136:403.

Tyler,M.J. 1976. *Frogs*. Collins, Sydney.

Tyler. M.J. 1989. Australian Frogs. Chapter 10 *The Cane Toad*. Viking O'Neil, Ringwood, Victoria.

Van Beurden, E.K. and Grigg. G.C. 1980 An isolated and expanding population of the introduced toad *Bufo marinus* in New South Wales. *Australian Wildlife Research* 7: 305-310.

Van Beurden, E. 1980. Mosquitoes (*Mimomyia elegans* (Taylor)) feeding on the introduced toad *Bufo marinus* (Linnaeus): implications for control of a toad pest. *Australian Zoologist* 20(3): 501-504.

Van Beurden, E. 1981. Bioclimatic limits to the spread of *Bufo marinus* in Australia: a baseline. *Proceedings of the Ecological Society of Australia* 11:143-149.

Van Dam, R.A., Walden, D.J. and Begg, G.W. 2002. A preliminary risk assessment of cane toads in Kakadu National Park. Supervising Scientist Report 164. Environmental Research Institute of the Supervising Scientist, Darwin.

Walker. R.F. and Whitford, W.G. 1970. Soil water absorption capabilities in selected species of anurans. *Herpetologica* 26: 411-418.

Waterhouse, D.F. 1974. The biological control of dung. *Scientific American* 230: 101-109.

Weber, N.A. 1938. The food of the giant toad *Bufo marinus* (L.) in Trinidad and British Guinea with special; reference to the ants. *Annals of the Entomology Society of America* 31:499-503.

White, A.W. 2003. Herpetofauna of Boodjamulla National Park and the Riversleigh World Heritage Area, north-western Queensland. *Herpetofauna* 33(2): 65-77.

Wolcott, G.N. 1937. What the giant Surinam toad *Bufo marinus* L. is eating now in Puerto Rico. *Journal of Agriculture University of Puerto Rico* 21: 79-84.

Woodford, J. 1996. Warts and all: embalmer sees cane toads as little treasures. *Sydney Morning Herald* 20 April 1996. P.6.

Zug, G.R., Lindgren, E. and Pippet, J.R. 1975. Distribution and ecology of the Marine Toad, *Bufo marinus*, in Papua New Guinea. *Pacific Science* 29: 31-50.

Zug, G.R. and Zug, P.B. 1979. The marine toad, *Bufo marinus*: a natural history resume of native populations. *Smithsonian Contributions to Zoology* (284): 1-58.