Pest risk assessment

Cane toad (*Rhinella marina* syn. *Bufo marina*)

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This publication has been compiled by Anna Markula, Steve Csurhes and Martin Hannan-Jones of Biosecurity Queensland, The Department of Primary Industries.

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Contents

Summary

In 1935, about 100 cane toads (*Rhinella marina* syn. *Bufo marina*) were introduced into Queensland from tropical America in a clumsy attempt to control cane beetles, a significant pest of sugar-cane crops. Over the past 90 years, cane toads have invaded most of coastal and sub-coastal Queensland, and are still spreading across northern Australia into north-west parts of Western Australia.

Adult toads are generally 10–15 cm long and can eat a wide range of invertebrate and small vertebrate prey items. Females can lay 8000 –35 000 eggs once or even twice each year. Cane toads have few predators due to their toxic paratoid glands, and under favourable conditions can become very abundant. While preferring open, disturbed habitats (especially gardens and lawns in urban areas), cane toads can also prosper in more natural habitats such as tropical woodland and savannah. They are less abundant or absent in dense vegetation.

While recognised as a somewhat iconic symbol of Queensland, cane toads have caused significant environmental harm. They are almost certainly causing the demise of certain species of unique native wildlife, especially the northern quoll. Their impact on a range of other animals (such as snakes, goannas, frogs and invertebrates) is somewhat unclear (especially at a long-term population level), but is generally perceived as significant.

Climate-based modelling of the long-term potential distribution of cane toads in Australia suggests further spread across tropical and subtropical coastal and sub-coastal northern Australia. For the most part, semi-arid tropical and subtropical areas are probably marginal

habitat, but cane toads might persist in low numbers in any moist areas (such as along river-banks and billabongs) within this zone.

Identity and taxonomy

Species identity: *Rhinella marina* (Linnaeus 1758)

Synonyms: *Bufo marina* (Linnaeus 1758), *Chaunus marinus, Bufo marinus*

Common names: cane toad, giant neotropical toad, marine toad, bufo toad, bullfrog, giant American toad, giant toad, Suriname toad, South American cane toad, giant marine toad, Dominican toad

Family: Bufonidae

A review of amphibian taxonomy placed *Bufo marina* in the *Chaunus* genus. Hence, some authors refer to it as *Chaunus marinus* (Frost *et al.* 2006). More recent molecular studies placed *B. marina* in the *Rhinella* genus as *Rhinella marina* (Chaparro *et al*. 2007). The currently accepted name is *Rhinella marina.*

Bufo comprises about 150 species of true toads found throughout most of the world, except for the Arctic, Antarctic, Australia, New Guinea and neighbouring islands. A unique feature of *Bufo* is a large parotoid gland behind each eye (Wikipedia 2009b). The genus *Bufo* was split multiple genera including *Rhinella* which is comprised of true toad species found throughout South America (Bonett *et al*. 2017). Refer to Nonindigenous Aquatic Species Database (2025) for more information on the taxonomic reviews of *R. marinus.*

Similar species: Some native burrowing frogs, especially the Giant burrowing frog (*Heleioporus australiacus*), are sometimes mistaken for *B. marinus*. Giant burrowing frogs can be distinguished by their more vertical pupils (Image 1). Perhaps the most distinctive feature of *B. marina* is a prominent sharp-edged ridge above each eye and the lack of bright colouring on the thighs (Wikipedia 2009a).

Image 1. Native giant burrowing frog *(Heleioporus australiacus*) (Photo: LiquidGoul, GNU Free Documentation Licence).

Description

Bufo marina is a heavily built amphibian. Adults are generally 10–15 cm long, with dry, warty skin that can be grey, yellowish, olive-brown or reddish-brown. The ventral surface is pale with dark mottling. *B. marina* is sexually dimorphic, with females growing significantly larger than males and having smoother skin. Males develop nuptial pads (dark lumps) on their first two fingers during the mating season. A median vocal sac also opens on each side of the mouth. Well-developed cranial crests form ridges above the eyes and join above the snout. The eyes are prominent and have horizontal pupils and golden irises. Adults have parotoid glands (large, triangular swellings) on each shoulder behind the eardrum. Hind feet are webbed, whereas front feet are not. *B. marina* adopts a more upright stance when sitting on flat ground, compared to native frogs. Juveniles have smooth, dark skin with darker blotches and bars, and they lack parotoid glands. Tadpoles are uniformly black and 22–27 mm long (Australian Museum 2003; CaneToadsinOz.com 2009; Easteal 1993; Wikipedia 2009a).

Image 2. Cane toad (*Rhinella marina*).

Biology and ecology

Tadpole development: Tadpoles emerge 48–72 hours after eggs are laid; tadpoles can develop into young toads (metamorphs) in 10 days – 6 months, depending on local conditions

Number of eggs: 8000–35 000 per clutch

Oviposition frequency: Once or twice per year

Sexual maturity: Reached when young toads are 65–90 mm in length, and are usually in their second wet season in northern Australia

Life span: At least five years in wild and up to 15 years in captivity (Australian Museum 2003; Hero & Stoneham 2009)

Breeding occurs throughout the year but tends to peak during periods of rain and warm weather. In Australia, breeding usually starts around September as temperatures begin to rise. Water temperatures of 25–30 °C are required for healthy tadpole development (Australian Museum 2003).

The male's mating call is a high-pitched 'brr' resembling the dial tone of a telephone (Gautherot 2000). Breeding sites are generally still or slow-flowing clear water, with salinity levels up to 15% and an alkaline pH (Australian Museum 2003; Hero & Stoneham 2009). Ephemeral water bodies are often optimal for breeding as they tend to be shallower and warmer, which maximises tadpole growth rate (van Dam *et al*. 2002). There is a clear preference for shallow pools with gradual rather than steep slopes, and open (un-vegetated) gradually sloping muddy banks. Sites with flowing water or with steep slopes and/or densely vegetated banks are avoided (Hagman & Shine 2006).

Fertilisation is external. Females lay their eggs within long, gelatinous strings (DEWHA 2005a). Environmental factors, such as temperature and water composition, can affect the gender ratio of tadpoles (Easteal 1993).

The length of the tadpole stage varies considerably, depending on climate, competition and the availability of food (Hero & Stoneham 2009). In the tropics, tadpoles mature more quickly than in temperate regions (Australian Museum 2003).

Where favourable conditions exist, tadpoles can form schools of tens of thousands. However, only about 0.5% of tadpoles survive to maturity.

Tadpoles can produce alarm pheromones in response to disturbance or injury. Moreover, both larval and post-metamorphic toads respond strongly to chemical cues from crushed or injured cohorts, consistently fleeing from the stimulus (Hagman & Shine 2008a). Tadpoles exposed to these pheromones metamorphose more quickly and at a smaller size than unexposed cohorts. When they mature, they also develop larger parotoid glands. The ability to invest varying resources into defensive toxins and to accelerate development is probably a response to predation pressure (Hagman *et al*. 2009).

During the dry-season when insect prey is scarce, some juvenile toads become cannibals. Individuals that are 80–110 mm long, can rapidly wave the long, middle toe on their hind foot to lure smaller toads. Up to two-thirds of total prey biomass can consist of metamorph toads caught in this manner, and the high densities of metamorphs around water bodies can provide exceptional feeding opportunities (Child et al. 2009, Hagman & Shine 2008b, Pizzatto & Shine 2008). The presence of cannibalistic individuals along the edges of waterways causes metamorphs to disperse, although this response can increase risk of desiccation (Child *et al*. 2008b). Since larger toads are nocturnal, diurnal activity by metamorphs is a behavioural response to avoid cannibalism (Pizzatto *et al.* 2008).

While in the process of invading new habitat, cane toads seem to enjoy a period of unusually high abundance. For example, densities of up to 2138 toads per hectare have been recorded at an invasion front in the Gulf of Carpentaria. Abundance seems to decline over time (Freeland 1986), presumably as food supplies become exhausted.

Adult toads tend to move more extensively during the wet season. During the dry-season, they seek shelter sites (such as deep burrows) that provide protection from desiccation (Schwarzkopf & Alford 2002). Males tend to stay around breeding ponds, calling to attract females, whereas females tend to wander over larger areas, feeding to accumulate energy needed to produce eggs (CaneToadsinOz.com 2009).

Diet

Cane toads are opportunistic, omnivorous and fearless predators and will eat almost anything they can catch and swallow. Their diet is predominantly comprised of small terrestrial arthropods (such as beetles, spiders, centipedes, millipedes, ants, winged termites and crickets), but also includes larger items such as marine snails, other (smaller) toads, frogs, small snakes, small mammals, small birds, earthworms, planarians, rotting fruit, carrion, household scraps and processed pet food. Adults can consume up to 200 food items per night, significantly more than native frogs.

After hatching, tadpoles initially feed on the gelatinous string that held the eggs together. Rasping mouth parts then allow tadpoles to feed on aquatic plants and detritus. Fine nutrient particles are ingested by filter feeding (Australian Museum 2003; DEWHA 2005a; Easteal 1993).

Predators and diseases

Predators include wolf spiders, freshwater crayfish, estuarine crocodiles, crows, white-faced herons, kites, bush stone-curlews, tawny frogmouths, water rats, giant white-tailed rats and keelback snakes (Australian Museum 2003). Keelbacks (*Tropidonophis mairii*) are more than 70 times more resistant to cane toad toxin than most other Australian snakes, and can regularly consume toads and survive. However, cane toads have lower nutritional value and take longer to consume than native frogs, and can also reduce locomotor ability for up to six hours after ingestion, possibly increasing the snakes' vulnerability to predation (Llewelyn *et al*. 2009).

Two species of meat ants (*Iridomyrmex purpureus* and *I. reburrus*) have been observed eating recently metamorphosed toads (Clerke & Williamson 1992). Compared to native frogs, very young cane toads appear less able to escape meat ants (Ward-Fear *et al*. 2009).

Some predators, such as crows, have learnt to eat only the tongue of *B. marina* or to attack the belly and eat only the mildly poisonous internal organs (Australian Museum 2003). They are often seen picking at toads that have been run over by vehicles on roads.

Tadpoles are consumed by dragonfly naiads, dytiscid beetles, water scorpions (*Lethocerus* sp.), notonectids (*Anisops* sp.), leeches, tortoises, *Macrobrachium* spp. and crayfish. The most frequent predators are older tadpoles (Hero & Stoneham 2009).

Cane toads carry the lung nematode *Rhabdias pseudosphareocephala*, which is native to South America. In metamorphs, infection causes reduced rates of survival and growth. Toads at the front line of their invasion path across northern Australia are free from these parasites (Dubey & Shine 2008).

B. marina in Darwin were been found to suffer from spinal arthropathy, as well as joint changes such as thinning cartilage. It is possible that the excessive physical activity at the invasion front predisposed them to degenerative joint changes (Shilton *et al*. 2008). *B. marina* is believed to carry the chytrid fungus, a significant disease of native frogs.

Origin and distribution

B. marina is native to regions from around 30° N in western Mexico and 27° N in the Lower Río Grande Valley in extreme southern Texas (United States), south through Mexico and Central America to around 30° S in Brazil and Argentina, including the Archipiélago de las

Perlas off the Pacific coast of Panama and Trinidad, Tobago and little Tobago off the coast of Venezuela.

The naturalised (introduced) range of *B. marina* adapted from (Lever 2003) includes:

- Asia—Japan (Ogasawara Islands, Ryukyu Islands), Philippines
- North America—Bermuda, Florida (United States)
- South America—West Indies (Antigua, Barbados, Carriacou), Cayman Islands, Grenada, Guadeloupe, Hispaniola (Haiti, Dominican Republic), Jamaica, Marie Galante, Martinique,
- Montserrat, Nevis, Puerto Rico, St Kitts (St Christopher), St Lucia, St Vincent, Virgin Islands
- Australasia—Australia, Papua New Guinea
- Oceania—Indian Ocean (Chagos Archipelago, Mascarene Islands), Pacific Ocean (American Samoa, Federated States of Micronesia, Fiji, Hawaiian Islands, Kiribati, Marianas Islands, Republic of the Marshall Islands, Republic of Palau, Solomon Islands, Tuvalu).

Figure 1. Worldwide distribution of *Bufo marina*—blue areas indicate native distribution and red areas indicate naturalised distribution (Source: LiquidGhoul, GNU Free Documentation Licence).

Status in Australia and Queensland

B. marina was introduced to Australia in 1935. The Australian Bureau of Sugar Experimental Stations imported about 100 toads from Hawaii to the Meringa Experimental Station near Cairns. They were released in an attempt to control French's cane beetle and the greyback cane beetle, the larvae of which eat the roots of sugarcane and kill or stunt the plants. The initial 100 toads bred quickly and more than 3000 were released in the sugarcane plantations of north Queensland in July 1935. There was a brief moratorium on further releases, following protest by some naturalists and scientists, but releases resumed in 1936 (Australian Museum 2003). Initially, cane toads spread south and west. They were first recorded in Brisbane in the 1940s, and occupied approximately half of Queensland by the late 1990s. They were recorded in north-eastern New South Wales in early 1960s, and crossed into the Northern Territory during the 1980s (DEWHA 2005a). The first cane toads invaded Kakadu National Park in the summer of 2000–2001 (Hero & Stoneham 2009).

At present, *B. marina* is abundant across vast areas of tropical and subtropical coastal and sub-coastal northern Australia, especially Queensland and northern New South Wales. Active invasion and population development is currently occurring in coastal Northern Territory and north-west Western Australia. The species' total range is estimated to cover more than 1 million km^2 across tropical and subtropical Australia (Phillips *et al*. 2007). Along the east coast of Australia, their range extends from Cape York Peninsular to Port Macquarie in New South Wales, with individuals regularly being found further south. In Queensland, small populations have been recorded as far west as Richmond and Roma.

Population expansion is most rapid in regions with hot weather, abundant breeding habitat, low elevation and high road density. In parts of northern Australia, invasion rates of 27 km per year have been recorded (Freeland & Martin 1985). There is evidence that cane toads utilise roads as dispersal corridors into previously unoccupied areas. In the Northern Territory, radio-tracked toads have been recorded moving up to 1.8 km per night along roads and cleared fence lines, avoiding heavily vegetated habitat and sheltering overnight close to these open corridors, returning to the road each evening to recommence dispersal (Brown *et al*. 2006). In less suitable habitat (such as hot, dry regions of the interior and in cooler regions in southern Australia) range expansion occurs more slowly.

Research has revealed that cane toads at the front of their invasion path have longer legs than animals in older, established populations. Longer legs probably facilitate more rapid dispersal. Populations during the 1940s to 1960s expanded at a rate of about 10 km per annum. The current expansion rate (> 50 km per annum) may be due to rapid adaptive change and continual spatial selection at the expanding front, favouring traits that increase dispersal such as longer legs (Phillips *et al*. 2006). In about 50 generations, *B. marina* in Australia have changed from populations in which many individuals move short distances and returned to the same shelter sites, to ones with a much higher proportion of toads likely to make long, straight moves to new locations every night (Alford *et al*. 2009).

Cane toads are readily moved over long distances by people. A study of toads in Sydney found that the main method of arrival was road transport (e.g. toads arriving as stowaways in landscaping supplies). The ability of *B. marina* to stowaway on road transport means they are highly likely to disperse across Australia, establishing new populations wherever suitable climate and habitat exists (White & Shine 2009).

Preferred habitat

In general, *B. marina* prefers humid tropical to subtropical lowlands, usually close to freshwater breeding habitat (Gautherot 2000). Disturbed or otherwise degraded habitats, where the original forest cover has been removed or damaged, appear most suitable, but open tropical savannah and forests with sparse understoreys are also suitable. Optimal habitat includes open cane fields, open grazing land, lawns and gardens. Cane toads tend to be much less common in closed forests or dense native vegetation, although they can occupy roads and tracks that run through such areas. Open sites such as urban lawns seem to suit the animal's hunting style of sitting waiting for insects and other prey to move past.

Cane toads hide during the day under rocks, fallen trees, loose boards or any shaded, cool cover they can find. They hunt at night, especially on warm, wet nights.

Habitat utilisation can vary, depending on seasonal conditions. For example, during the dry season in Kakadu National Park, Northern Territory, cane toads congregate close to creeks, billabongs and patches of monsoon rainforest (where there is moisture). During the wet season, however, they disperse much further into woodlands and open forests of the lowland plains (van Dam *et al*. 2002).

Adults tolerate brackish water and have occasionally been seen swimming in the sea. They readily inhabit the margins of estuaries, tidal mudflats, coastal dunes and coastal mangroves (van Dam *et al*. 2002).

Cane toads can tolerate the loss of up to 50% of their body-water, and can survive in areas where temperatures range from 5 to 40 °C (Australian Museum 2003). Cane toads occupy habitats at elevations ranging from sea level up to 1600 m (Hero & Stoneham 2009).

History as a pest elsewhere

B. marina is one of the most widely distributed terrestrial vertebrate pests in the Pacific and Caribbean regions (Lever 2003). The species was introduced to many tropical countries and islands in a clumsy attempt to control pests affecting agriculture. For example, introductions into Jamaica and the Philippines in the late 1800s were aimed at controlling rats. Similarly, releases into Puerto Rico, Fiji, New Guinea, Hawaii, America and Australia in the early 1900s were to control sugarcane pests (Hero & Stoneham 2009). In some areas, *B. marina* failed to establish or there was an initial population increase followed by a strong decline.

Many countries consider *B. marina* to be either a minor pest or a beneficial form of insect control. In some places, their impact on native fauna is recognised. For example, in the Philippines, it is believed to compete with native frogs for breeding sites and food (Lever 2003). In Papua New Guinea, *B. marina* may have caused a decline in the abundance of certain native predators such as the Papuan black snake (*Pseudechis papuanus*) and New Guinea quolls (*Dasyurus albopunctatus*) that have either mouthed or consumed toads (Lever 2003).

B. marina is a pest of apiarists in Australia and Bermuda, since they eat bees as they leave or enter their hives. Honey production losses of over $1 million per year have been estimated.

In Barbados, *B. marina* is considered a pest of plant nurseries, due to its habit of burying itself in moist potting mix, thereby crushing delicate seedlings. Similarly, *B. marina* causes damage to seed beds in Grenada and tramples commercial lettuce beds on St Lucia in the West Indies (Bomford *et al*. 2005).

Current impact in Australia

B. marina has invaded large areas of tropical and subtropical Australia across a range of habitats. While there is a general perception that it has significant negative impacts on native wildlife (especially predators), there is limited quantitative information (especially on long-term impacts). Most information is anecdotal or inconclusive at a population or species level (DEWHA 2005a).

Native predators that have died after eating, or attempting to eat, cane toads include goannas, freshwater crocodiles, tiger snakes, red-bellied black snakes, death adders, dingoes and quolls (Australian Museum 2003). The northern quoll (*Dasyurus hallucatus*) has suffered a serious population decline and *B. marina* is listed as a 'Key Threatening Process' for northern quolls under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. In some areas, such as Cape York and Kakadu National Park, quolls rapidly disappeared following the arrival of *B. marina*, and populations have not recovered (DEWHA 2005b).

Letnic *et al.* (2008) found that cane toads caused a 45–77% decline in abundance of freshwater crocodiles (*Crocodylus johnstoni*) in the Victoria River region of the Northern

Territory. Subadult crocodiles suffered highest mortality rates. The removal of these top-order predators is likely to have serious flow-on effects within riparian and aquatic ecosystems in the Northern Territory.

Another study in the Northern Territory found that cane toads caused marked declines in populations of yellow-spotted monitors (*Varanus panoptes*). Monitors have been reduced to such low numbers that they are no longer significant predators of pig-nosed turtle eggs (*Carettochelys insculpta*). Prior to the arrival of *B. marina*, annual losses of pig-nosed turtle eggs were 17–23%. Following invasion, losses of pig-nosed turtle eggs no longer occurred (Doody *et al*. 2006). Increased numbers of pig-nosed turtles will probably have flow-on effects for other species

Research on rainbow bee-eater birds (*Merops ornatus*) in south-east Queensland found that *B. marina* predation caused 33% of nests to fail. *B. marina* were observed to occupy the birds' nest burrows for several days, or even weeks, either eating the eggs or small chicks, or starving larger chicks by preventing adult birds from entering their burrows (Boland 2004).

A study on the effect of *B. marina* toxin on a variety of frog-eating snake species identified 49 species that are potentially at risk. Nine of these species are listed as 'threatened species' at either federal or state levels. Moreover, *B. marina* pose a potential threat to 70% of Australian colubrid snakes, 40% of pythons and 41% of elapids (Phillips *et al.* 2003).

Seventy-five species of Australian lizards, crocodiles and freshwater turtles are threatened by cane toads. Sixteen of these are 'threatened species' at either federal or state levels (Smith & Phillips 2006).

Reptile species that appear to have adapted to *B. marina* include the keelback (*Tropidonophis mairii*) and the Australian black snake (*Pseudechis porphyriacus*). In less than 23 generations, the black snake population appears to have developed increased resistance to *B. marina* toxin and an increased reluctance to consume toads (Phillips & Shine 2006).

The tadpoles of native frogs can die if they consume the eggs of *B. marina*. *B. marina* tadpoles have been recorded to reduce the growth rates of native frog tadpoles under certain conditions. Fortunately, *B. marina* utilises a smaller range of water bodies for breeding and, as such, interaction between *B. marina* and native frog eggs and tadpoles does not always occur. However, the full extent of interaction and mortality is unknown (Crossland *et al.* 2008; Williamson 1999).

In the Northern Territory, several Aboriginal communities noticed a decline in 'bush tucker' species such as monitor lizards, snakes and turtles. There has also been a loss of totem species such as freshwater crocodiles, which are important for traditional ceremonies (van Dam *et al*. 2002).

When an area is first invaded by *B. marina*, the naturally high abundance of invertebrates appears to support a total biomass of *B. marina* that is up to four times greater than the local frog population (Greenlees *et al*. 2006). As food items are exhausted, *B. marina* abundance appears to decline, presumably until it is more or less in equilibrium with its food supply. The initial decline in invertebrate prey items that follows the toad invasion front probably has significant flow-on effects to other insectivorous predators and may interrupt ecological processes, at least temporarily. The significance of these effects and their timescale is largely unknown. Some studies have shown that the impact on certain native species may not be as severe as first thought. For example, planigales (*Planigale maculate*) were shown to readily consume metamorph *B. marina*. Most survived the initial encounter and quickly learnt to avoid *B. marina*, for up to 28 days. It has been suggested that they have learnt to use chemical cues to discriminate between frogs and *B. marina* following initial interaction.

Hence, there is hope that small dasyurid predators might adapt to *B. marina* invasion over the long term (Webb *et al.* 2008).

Greenlees *et al*. (2007) found that the presence of *B. marina* did not influence food intake or dietary composition of the morphologically similar native giant burrowing frog (*Cyclorana australis*). However, high densities of anurans (frogs and toads) suppressed frog activity levels.

For further information on impact refer to McRae *et al*. (2005).

Pest potential in Queensland

Since *B. marina* is currently spreading west across northern Australia, it is important to try and predict its full potential range.

Climate match

A species' distribution is determined by a complex range of environmental variables. However, climate appears to be one of the most influential parameters. Using a climate-based modelling tool called CLIMEX (Skarratt *et al*. 1995), this study suggests that large areas of coastal and sub-coastal tropical northern Australia have climate types that are highly suitable for *B. marina* (Figure 2).

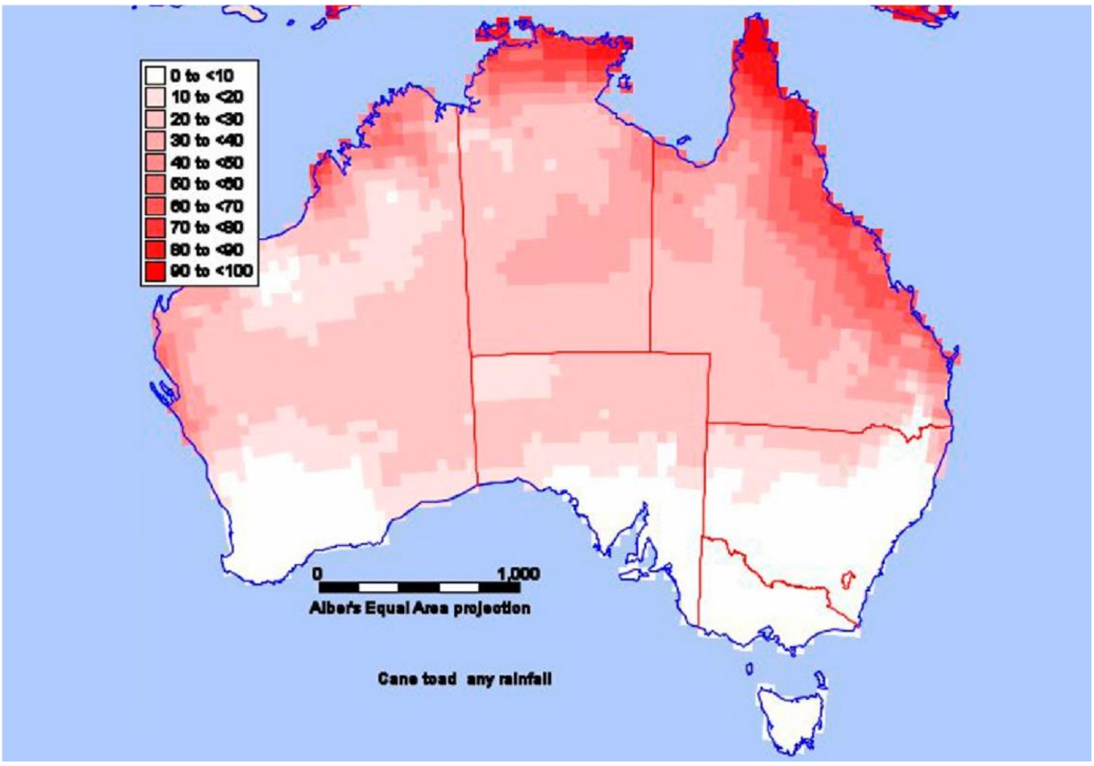

Figure 2. Potential distribution of *Bufo marina* in Australia, as predicted by climate-matching computer software called CLIMEX—areas coloured darkest red indicate areas where climate is considered highly suitable, grading to lightest red which indicate marginal habitat; white indicates unsuitable habitat (model produced by Martin Hannan-Jones).

The species' predicted range in Queensland is similar to its current observed range, suggesting it has filled much of its potential bio-climatic range in the state. The potential for further spread into Queensland's far western arid zone is open to speculation—while the climate may be generally too hot and dry in this area, *B. marina* might survive within small pockets of moist habitat, such as along the banks of watercourses. This model suggests that *B. marina* is unlikely to spread south past Port Macquarie in New South Wales (where it currently exists) and that large areas of southern Australia are climatically unsuitable.

The climate-based prediction of potential range presented above can be compared to other published models. To date, there have been two main approaches used to model and predict the potential range of *B. marina* in Australia—correlative and mechanistic. The former, published by Urban *et al*. (2007), was based on presence and absence data. It used a number of climatic variables recorded across the naturalised range of *B. marina*, namely annual temperature, annual precipitation, minimum moisture index, mean annual evaporation, elevation, topographical heterogeneity, road cover and urban land use. This model predicted that *B. marina* could eventually occupy 2 million km^2 of Australia, including 76% of the coastline.

The mechanistic approach, published by Kearney *et al*. (2008), does not use species' occurrence data. Instead, it links key eco-physiological traits with spatial data using biophysical models. This model predicts that the major constraints to potential range in Australia may be climatically imposed limitations on movement potential in adult *B. marina* at southern range borders, and the availability of water for breeding in natural ponds at the interior limit. It predicts *B. marina* will not survive in large parts of southern Australia, but may occupy extensive areas of central Australia.

The potential impacts of cane toads are difficult to predict. However, based on available evidence, it seems reasonable to expect further declines in certain native predator populations. Native predator species that adapt by learning not to eat toads may recover. Further research is needed to predict impacts.

Threat to human health

At all developmental stages (including eggs) tadpoles and adults are poisonous, though young tadpoles are the least toxic. Paratoid glands just behind the head produce and store a mixture of bufotenine and epinephrine, which are steroid-like substances toxic to most animals. These substances have a digitalis-like action on the heart.

Humans poisoned by *B. marina* experience vomiting, increased blood pressure, increased pulse rate, increased rate and depth of respiration, severe headache and paralysis. While there have not been any deaths in Australia, people have died overseas after eating toads or soup made from toad eggs. People have been reported to smoke the dried parotoid glands or lick the back of toads for hallucinogenic effects produced by the toxins. This form of substance abuse has occurred in north Queensland and in Fiji.

Domestic pets such as dogs and cats, and native wildlife can be poisoned, often with fatal consequences. Symptoms include rapid heartbeat, profuse salivation, twitching, vomiting, shallow breathing and collapse of the hind limbs. Death from cardiac arrest may occur within 15 minutes.

B. marina responds to a threat by turning side-on so its parotoid glands are directed towards the attacker. The toxin usually oozes out of the glands, but toads can squirt a fine spray for a short distance if they are handled roughly. The toxin is absorbed through mucous membranes such as eyes, mouth and nose, and in humans may cause intense pain, temporary blindness and inflammation (Australian Museum 2003; Hero & Stoneham 2009; Nellis 1997; van Dam *et al*. 2002).

Numerical risk analysis

A numerical risk assessment system developed by Bomford (2008) is widely applied in Australia to assess the level of risk posed by vertebrates. This approach enables numerical ranking and prioritisation of large numbers of species. Firstly, a species' potential distribution is predicted using climate-modelling computer programs. The remaining steps involve allocation of scores for a number of attributes relevant to a species' pest status, including biology, costs to the economy, the environment and society, and management efficacy.

Using the Bomford system, cane toads were assessed as an 'extreme' threat species (refer to Appendix).

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Appendix

Using the Bomford (2008) system, cane toads in Queensland were ranked as an 'extreme' threat.

Table 1. Australian bird and mammal model.

Species:		*Rhinella marinus* (cane toad)
Date of assessment:		**2 April 2009**
Literature search type and date:		**See references**
Factor	**Score**	
A1. Risk to people from individual escapees (0–2)	2	Cane toads are capable of causing fatalities or serious injury to people
A2. Risk to public safety from individual captive animals (0–2)	1	Moderate risk that toxins of captive animals pose a public safety risk
Stage A. Public safety risk rank = sum of A1 to A2 (0–4)	**3**	**Highly dangerous**
B1. Climate match (1–6)	5	Very high climate match in Australia (CMS = 2041)—from climate map produced by DAFWA in 2008 using PC Climate software (Bureau of Rural Sciences 2006)
B2. Exotic population established overseas (0–4)	4	Cane toads have established in Australia and across the Caribbean and the Pacific
B3. Overseas range size (0–2)	1	Overseas range size of 16.2 million square kilometres (Bomford et al. 2005)
B4. Taxonomic class (0–1)	1	Amphibian
B5. Diet (0–1)	1	Generalist diet of small terrestrial arthropods, such as crabs, spiders, centipedes, millipedes, scorpions, beetles, honeybees, ants, winged termites, crickets and bugs They are also known to consume marine snails, smaller toads and native frogs, small snakes, small mammals, birds, earthworms, planarians, rotting fruit, carrion, household scraps, processed pet food and human faeces
B6. Habitat (0–1)	1	Cane toads thrive in degraded and human-made environments.

B7. Migratory (0-1)	1	Non-migratory.
B. Probability escaped or released individuals will establish a freeliving population = sum of B1 to B7 (1–16)	**14**	**Serious Establishment Risk**
C1. Taxonomic group (0–4)	0	Other group
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2)	1	Approximately 16.2 million square kilometres (Bomford et al. 2005)
C3. Diet and feeding (0–3)	0	Not a mammal
C4. Competition with native fauna for tree hollows (0–2)	2	Cane toads are known to shelter in tree hollows
C5. Overseas environmental pest status (0–3)	3	Major environmental pest in Australia
C6. Climate match to areas with susceptible native species or communities (0–5)	5	The species has more than 20 grid squares within the highest two climate match classes, and has more than 100 grid squares within the four highest climate match classes, that overlap the distribution of any susceptible native species or communities
C7. Overseas primary production pest status (0–3)	2	Cane toads are a pest to apiarists and can cause significant losses
C8. Climate match to susceptible primary production (0–5)	1	Total commodity damage score = 7.5 (see Table 2)
C9. Spread disease (1–2)	1	Amphibian
C10. Harm to property (0–3)	0	$0
C11. Harm to people (0–5)	4	Injuries or harm severe or fatal but few people at risk—people have died after consuming cane toads or their eggs, and their poison can cause temporary blindness
C. Probability an exotic species would become a pest (for birds, mammals, reptiles and amphibians) = sum of C1 to C11 (1–37)	**19**	**Serious pest risk**

Stage A. Risk to public safety posed by captive or released individuals. (Public safety risk score = 0—not dangerous; 1—moderately dangerous; ≥2—highly dangerous)	3	Highly dangerous
B. Risk of establishing a wild population		
For birds and mammals: B < 6 = low establishment risk; B = 7–11 = moderate establishment risk; B = 12–13 = serious establishment risk; B > 14 = extreme establishment risk		
For reptiles and amphibians: B < 3 = low establishment risk; B = 3–4 = moderate establishment risk; B = 5–6 = high establishment risk; B > 6 = extreme establishment risk	14	Extreme establishment risk
C. Risk of becoming a pest following establishment		
C < 9 = low pest risk; C = 9–14 = moderate pest risk; C = 15–19 = serious pest risk; C > 19 = extreme pest risk	17	Serious pest risk
Vertebrate Pests Committee threat category		**Extreme**

Table 2. Calculating total commodity damage score.

Industry	Commodity Value Index[1] (CVI)	Potential Commodity Impact Score (PCIS, 0-3)	Climate Match to Commodity Score (CMCS, 0-5)	Commodity Damage Score (CDS, columns 2* 3 *4)
Cattle (includes dairy and beef)	11	0	Not estimated	0
Timber (includes native and plantation forests)	10	0	Not estimated	0

Cereal grain (includes wheat, barley sorghum etc.)	8	0	Not estimated	0
Sheep (includes wool and sheep meat)	5	0	Not estimated	0
Fruit (includes wine grapes)	4	0	Not estimated	0
Vegetables	3	0	Not estimated	0
Poultry and eggs	2	0	Not estimated	0
Aquaculture (includes coastal mariculture)	2	0	Not estimated	0
Oilseeds (includes canola, sunflower etc.)	1	0	Not estimated	0
Grain legumes (includes soybeans)	1	0	Not estimated	0
Sugarcane	1	0	Not estimated	0
Cotton	1	0	Not estimated	0
Other crops and horticulture (includes nuts, tobacco and flowers)	1	0	Not estimated	0
Pigs	1	0	Not estimated	0
Other livestock (includes goats, deer, camels, rabbits)	0.5	0	Not estimated	0
Bees (includes honey, beeswax and pollination)	0.5	3	5	7.5
Total Commodity Damage Score (TCDS)	**—**	**—**	**—**	**7.5**

* The commodity value index is an index of the value of the annual production value of a commodity. For a full explanation refer to Bomford (2008).