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# Effectiveness of Cane Toad Eradication Methods: Arakwal National Park

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*SIT Study Abroad*

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# Effectiveness of Cane Toad Eradication Methods: Arakwal National Park

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## **Abstract**

The cane toad (*Bufo marinus*) is a pest throughout Australia. Not only is it poisonous to native predators, it also consumes or out competes native fauna. It has only recently entered into Northern New South Wales where the site for this study is located, at Arakwal National Park. This study aims to discover the most effective method of cane toad eradication in the National Park.

Over the course of 18 days, three traps were set and rotated between 9 different sites. Traps were set at sunset and cleared at sunrise. The three traps used were; (1) Pitfall style trap by Mr. Paul Baker, winner of the Northern Territory trap competition, (1) two-gate Frogwatch trap, and (1) three-gate Frogwatch trap. The lights on the traps were connected to batteries that supplied constant light to attract bugs which in turn attract cane toads. In all seven toads were caught, five by the Pitfall trap and one each by the Frogwatch traps.

Ten of the 18 days were used for manual collection of eggs, tadpoles, metamorphs, and juvenile. One hour per day was spent for egg/tadpole collection and one hour for metamorph/juvenile collection. In egg/tadpole collections, no eggs and 2569 tadpoles were collected over the ten days. In metamorph/juvenile collections 176 were caught over the ten-day period. To compare the collections of egg/tadpole and juvenile/metamorph to toad trappings, high and low ranges for survival rates were applied to both collections.

Using the survival rates from the high end of the range, .04 expected adults were captured in tadpole collections and .22 in metamorph collections per hour of labor. The mean of adult toads caught with traps per half hour was .39. This shows that cane toad trapping was more effective based on overall expected adults caught. The variance of the distribution of each method was also calculated, resulting in that trapping adult toads had the least amount of variance over all.

Trapping adult toads was found to be most effective in cane toad eradication and also the most probable means of catching individuals. This study agrees with previous research that suggests the most effective measures of cane toad eradication target adult populations and not other life stages.

**ISP TOPIC CODES** 537 *Environmental Studies*, 608 *Forestry and Wildlife*, 609 *Biology*

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**CSIRO** – Commonwealth Scientific and Industrial Research Organization

**NPWS** - National Park and Wildlife Service

**NSW** – New South Wales

**SIL** - snout-ischium length

# 1 Introduction

Cane toads are an invasive species and alien to Australia, they were first introduced in Australia in 1935. The cane toad, *Bufo marinus*, is native to Central and South America, and was brought to Queensland to control two sugar cane pests, the Frenchi cane and Greyback cane beetles. This proved highly unsuccessful, although the cane toad would predate on the beetles, the instance to do so was highly unlikely because of the sugar cane environment and the wide range of the cane toad's diet. Simply put, it was not reliant on the beetles and they did not often present themselves as easy feed (Queensland 2006).

The introduction was not by accident; the original 101 cane toads were released by Australian Bureau of Sugar Experimental Stations, in Gordonvale, Queensland (CSIRO 2003a). The first toads were not from South America but transferred from Hawaii, where they had also been introduced. It was with ill foresight and lack of scientific data that led to one of Australia's most prolific invasive species (Australian Government: Department of the Environment and Heritage 2004).

## 1.1 Life Cycle

The advantages the cane toad has to spread are obvious from day one, fertilization. The female cane toad averages between 8,000 - 30,000 eggs in a single lay. This is in contrast to most native frogs, which on average lay 1,000-2,000 eggs at a time. Cane toad eggs are usually present in shallow, slow moving waterways such as creeks, dammed or flooded areas. They come packaged in long "gelatinous" strands and contain "double rows of black eggs." The strands become entangled in debris like plant matter and rocks until they hatch. Hatching usually takes place 48-72 hours after the eggs are laid (CSIRO 2003a). At this point it becomes an aquatic larvae also known as a tadpole.

The tadpole is black and usually smaller than its native counterparts. The under belly is black like the rest of the tadpole, while similar native tadpoles bear clear bellies. The tail is also short in comparison to native tadpoles. The native *Crinia* species are similar to the cane toad tadpole, but is distinctive by its, “the more prominent gold iridophores.” Ways to distinguish them from native species is that cane toad tadpoles travel in large groups, similar to a school of fish. Their bodies are all black lacking any color (Anstis 2002).

Tadpoles of the cane toad have very interesting and unique behaviors. They prefer shallow, slow moving, to stagnant water. On sunny days they can be seen at the edge of the shore, in large groups. They are very hardy eaters and will cannibalize their own kind as well as native tadpoles, either alive or dead (Anstis 2002). The research of Lampo and de Leo (1998) suggests that cane toad tadpoles have better chances of survival in smaller groups, and that removal of tadpoles from large group only encourages the survival of those left behind.

Tadpoles have a relatively short phase, proceeding into metamorphoses in as little as 14-28 days. Survival rate of tadpoles are around 1.4% at equilibrium, or in the most likely of circumstances. This is depended highly on the temperature of the water; warmer temperatures speeding the process to metamorphosis (Lampo & del Leo 1998 p. 389-92). After this the cane toad tadpole leaves its watery habitat transforming to a metamorph as it changes towards a toad. The metamorph stage is defined as a terrestrial toad, 9-29 mm snout-ischium length (SIL) as used by Cohen and Alford (1993, p. 1). During this stage some distinguishing characteristics start to reveal themselves; orange spots followed by and enlarging parotid glands, where their infamous toxin is stored. Early on in the metamorph stages, they can be hard to identify, as the orange spots are not present when newly emerged from the water (Cohen & Alford 1993 p. 1). They usually arrange themselves around water until a week or so after coming ashore.

Metamorph survival onto juvenile in Australia is said to be between 1.2-17.6 % (Lampo & del Leo 1998 p. 390). After the toad grows past the 30 mm SIL they are considered at the juvenile stage. It is at this stage that they have completed metamorphosis from tadpole to toad and now begin their growth to an adult. Survival from juvenile to adult ranges from 3-7% in Australia (Lampo & del Leo 1998 p. 390). For practical purposes the metamorphs and juveniles are often lumped together as toadlets (Queensland 2006).

At 89 mm SIL the juvenile stages is typically over although it can happen at smaller sizes. At this stage the “secondary sex characteristics are always well developed,” states Cohen and Alford (1993, p. 2). This usually occurs within 6 – 18 months (CSIRO 2003a). The adult cane toad is quiet large in relation to native fauna, reaching sizes of over 20 cm. Along with its sheer size the adult has many features that one can use to discern it from native frogs.

The most noticeable feature of the adult cane toad is the prominent parotid glands located on the dorsal side behind each ear (Queensland 2006). These glands store the cane toad’s toxin. This toxin, also known as bufotoxin, is compromised of a few poisons; the main one is cardioactive, acting on the heart (Vanderduys & Wilson 2000). The dorsal side or top side of the toad is usually a brown, but sometimes has tints of green or red. The belly of the beast is whitish with brown or black spots.

The eyes are another key characteristic, as a visor covers each, with a ridge on the nose between the eyes. Unlike native frogs, the cane toad lacks discs on its digits which aid in climbing. It also has smaller hands and feet than native frogs, with webbing only on its hind feet. These features make the toad a poor climber and therefore a ground dweller. One can tell the males from the females as the males are usually smaller and have substantially more warts, while the females are larger (Queensland 2006 p. 2).

## **1.2 Damage**

The two characteristics that make it an extreme pest are the parotid glands with their bufotoxin and the wide range of the cane toads diet. The toxin will be excreted, or in some cases squirted, from the gland when it is disturbed or threatened. The cane toad can and will eat anything that can fit into its mouth, including small rodents, reptiles, native frogs, tadpoles (their own and otherwise), marsupials, and insects (Department of the Environment and Heritage 2004).

In a recent study done on snakes (Phillips, B. Brown, G. & Shine R. 2003), they identified 49 species that are at potential risk from cane toad toxin. Of these 49, they tested tens resistance to bufotoxin, examining its movement after being given a small dose. Of the ten, seven species were estimated to die from eating one cane toad. However, two of the species were found to be highly resistant, the keelback and the slatey-grey snakes.

There are some predators that have found ways to consume the cane toad. The tadpoles are predated on by; “dragonfly nymphs, water beetles, Saw-shelled Turtles and keelback snakes,” the latter of which has built a small resistance to the toxin. In the instance of the adults, many species have found ways to avoid the toxic glands by going for its belly or only eating certain parts of the toad, these include; “wolf spiders, freshwater crayfish, Estuarine Crocodile, crows, White-faced Heron, kites, Bush Stone-curlew, Tawny Frogmouth, Water Rat and the Giant White-tailed Rat,” (Department of the Environment and Heritage 2004).

## **1.3 Spread**

The cane toad has rapidly increased since its initial introduction, in both population and territory. It currently has made it far south as Northern New South Wales and forced its way into the wetlands of the Northern Territory. Its habitat currently includes 50% of

Queensland as can be seen in Map 1. One concern is that its spread will only increase with predicted climate change as colder temperatures currently limit it. (Sutherst et al 1996 p. 1).

**Map 1 – adapted from (Australian Government: Department of the Environment and Heritage 2004)**

**(/images/map01.jpg)**

Because of the threat it poses to native fauna and its ever-continuing spread, many methods for control have been advocated by various organizations and governments. There are currently two different approaches to cane toad control; physical removal and biological control.

#### **1.4 Methods of Control**

Physical removal was the original method of control for the cane toad. It involved capturing a cane toad individual in some way and killing it. It is participated in many ways from “toad busting” events, in which participants canvass an area in search of the creature, to drivers purposefully hitting of toads with cars (Frogwatch 2006b). The latter is not recommended for it has high probability of false identification. The currently used accepted control methods are collections; of eggs through adults, and trappings.

Collections of cane toads and their offspring is a labor intensive activity. For eggs and tadpoles it involves treading into shallow waters with a net in search of the characteristic schools of black tadpoles or gelatinous strands of eggs. Upon netting either a proper identification is needed and sorting of native species out and back into the waterway. This by-catch can be avoided if one only captures the tadpoles in the large groups, as native tadpoles rarely are in these groups.

Collections of metamorphs are usually done near the shore of bodies of water, they are picked up by hand. When collecting metamorphs, great care is needed in identifying the

individual correctly as a cane toad. They lack the distinguishing features of an adult but have the white spotted belly and orange spots on its dorsal side. Juveniles and Adults are caught in a similar manner to metamorphs, however spotting them during the day is more unlikely.

There is little research on the effectiveness of collections. “Toad Busting” reports include tadpoles through adults caught, but rarely list the amount of time used for quantification of the labor per toad eliminated. An example of the data collected can be seen in the March 2006 issue of Toadbuster News, in which they say 3300 toads were captured and 2.5 liters of tadpoles, with no mention as to labor involved, only number of participants (Frogwatch 2006b).

The second method of physical removal, trapping has been more widely used than collections, but is still prevented from going mainstream by lack of research and funds. The success of these traps has been documented highly by FrogWatch and the Northern Territories government. In one trial (Sawyer 2005), a single trap caught 224 toads in its first week and by week six the amount steadily declines to 24. This was using a three-gate trap made by Frogwatch. This report suggests that the overall population in an area can be substantially affected by trapping. The estimate was that the population had been reduced by 70%. There are some flaws with these estimates, as it assumes that 100% of toads are susceptible to trapping, but offers promising results for the trapping initiative.

The Northern Territory Government held a competition hailed, “The Great Cane Toad Trap Competition.” They asked Northern Territorians to design traps to best capture cane toads. There were six finalists and one winner, a Mr. Paul Baker who designed a pit-fall style trap design. In tests done to determine the winner, 112 toads were trapped by Mr. Baker’s trap, the next finished at 73. This is the only available test done on this trap (Northern Territory Government: Natural Resources, Environment and the Arts 2006).

Biological control is currently where most emphasis is being placed in the battle against cane toad spread. The main research organization in this endeavor is CSIRO, sponsored by the Australian Government. At one stage it was thought a method of biological control was found, in the cane toad virus from Venezuela. This proved to be a dangerous undertaking as it also killed native frogs in laboratory; it was never released in to the Australian environment (CSIRO 2003b).

Currently CSIRO is pursuing methods of biological control. One method that seems promising is some agent interfering with cane toad metamorphosis. Metamorphosis is the change from tadpole to toad, and interfering with this would prevent the toad from becoming an adult and mating. Their first goal is to find a gene that they can manipulate that interferes with metamorphosis. The second is to find a virus or some carrier on which they can spread it through the toad population. Like the original Venezuela cane toad virus, much care is needed to prevent a possible epidemic killing native fauna (CSIRO 2003b).

This study examines aquatic (tadpole and egg) collections, toadlet (juveniles and metamorphs) collections, and trapping of juveniles and adults toads. The traps used are; (1) FrogWatch two-gate Trap, (1) FrogWatch three-gate Trap, (1) Pitfall Trap by Mr. Paul Baker winner of the Northern Territory competition.

### **1.5 Trap Description**

The FrogWatch traps are described as; “a one-way gate developed by Graeme Sawyer with assistance from David Wilson and Ian Morris. The one-way gate utilizes clear plastic fingers that allow the toads to see into the trap and allows them to easily push into the trap. Once inside the trap the toads cannot get out again,” (FrogWatch 2006b). These traps employ a more common gate method of trapping. The cages are made of wire with one-inch spaces between wire pattern as can be seen in Figure 1.

**(/images/figure01.jpg)**

### **Figure 1 - FrogWatch three-gate Trap**

The Pit Fall trap is described; “ramps provide easy access to the top of the trap with a series of trap doors in the top of the box. Approximately 50% of the top surface is trap-door space. The light source on vertical panel reflects light out over the trap top. The combination of reflected light across the trap surface and such a large area by which the toads could enter the trap” (Northern Territory 2006). This trap takes a much different approach, unlike the FrogWatch traps; it is completely concealed with no gaps in the frame, disallowing those caught to escape if small enough as can be seen in Figure 2.

**(/images/figure02.jpg)**

### **Figure 2 - Pitfall Trap**

The aims of this study are: 1) to determine which physical removal method is most effective in eradicating cane toads from Northern New South Wales’ Arakwal National Park, 2) Identify trends to make these methods as efficient as possible and 3) identify most effective cane toad trap. Much is being done on the research for a biological control method; however, the currently physical removal methods of control are being ignored. More research is needed to find what effectiveness they have and encourage use, if shown to be effective, to mitigate the cane toads’ spread. Until, if ever, a biological method is discovered, other endeavors need to be examined and used to make sure there is something to save.



## **2 Methods**

### **2.1 Location**

The site chosen for this study was a portion of Arakwal National Park in Northern New South Wales, Australia. The area is located at 28° 39' 23.11" S and 153° 37' 26.13" E (Google Earth 2006). The area included in the study is used partially as an access point for residents and visitors to Tallow Beach from Beachcomber Road. It is an unmarked access so the number of people using it is very limited. All of the area surveyed is part of an "Investigation area for rehabilitation of ephemeral wetlands," as you can see marked on Map 2. The area used in the study was all within those boundaries.

**(/images/map02.jpg)**

### **Map 2 - Map Arakwal National Park altered (Department of Environment and Conservation NSW: National Parks and Wildlife Service 2004)**

In the northern part of the wetland area one can see the former dredge pond. This was created during sand mining in past years and was left behind as a result of the operation. The pond is considered a major threat to native frog species and in fact all fauna, as it is the only permanent freshwater in the area and a breeding ground for cane toads. At one time the NSW National Parks and Wildlife Service attempted to fill the pond and return it to wetland like the surrounding area. They felt by returning it to seasonal wetland that it would decrease the cane toads' strangle hold on the area. It has since fully returned to a pond (Department of Environment and Conservation 2004).

### **2.2 Flooding of the Wetland**

The area, upon the first observations on 4/13/06, when accompanied by a NPWS ranger appeared to be a field of grass surrounded by vegetated dunes on the east and west

side. On 4/16/06 there was a significant rain event of 146.4 mm followed by another 2.0 mm on the 17<sup>th</sup>. This significantly flooded the wetland area and much of my approach changed to meet the new conditions. The extent of the flooding is shown in Map 3.

The site was chosen because it had been identified by previous studies, commissioned by the national park, as an area under threat by cane toad presence. It contained what was considered by that study to be a breeding ground for the toads at the former dredge pond (Department of Environment and Conservation NSW: National Parks and Wildlife Service 2004). The encouragement and assistance of the national park rangers also led to the decision to use this site. They had attempted to use traps in the past with mixed success and offered their traps for use in the study. The site also proved to be ideal for conducting this type of research; it had relatively easy access coupled with limited human activity.

### **2.3 Trap Site Placement**

As a result of the flooding of the wetland, I was forced to abandon my original plan of choosing trapping sites around the perimeter of the former dredge pond. Access to the pond was not feasible so new locations were chosen near the entrance from Beachcomber Road. Sites were changed weekly so newly dried areas could be utilized. Sites were always moved towards the most preferable location based on previous studies and information. This was usually near a water source in a flat area with low cut grass.

The three traps were placed at three different sites with at ten meters between them. The traps were moved after each night to the next location in the line up. Six-day periods were used, as there were three traps and three sites. Each trap would be set at each of the three sites twice. This is demonstrated by the first six-day round in Table 1. After when the first six-day round was over, three new sites would be chosen and the traps would follow the same rotation. In all nine sites were used the traps used at each site twice for a total of 18

nights. One night was “rerun” because of failure of a light, but after more failures it was determined this “rerun” would be eliminated from the study.

**Table 1 – Week one trap rotation**

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Pitfall Trap	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2
2-gate trap	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
3-gate Trap	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1

The traps were set at night as close as possible to sunset to insure the longest battery and life light as the lights are only effective in attracting bugs when dark. The traps were cleared; removed of any toads and unplugged as close as possible to sunrise, again to preserve battery life and to avoid subjecting the toads to the heat of the sun, where they may be subject to undue pain.

The sites for trapping can be seen on Map 3. Each site used was on an area with short to no grass. The surrounding area varied from mudflat to tree covered area. The last week of trapping all of the traps were within 2 meters of the water.

*(/images/map03.jpg)*

**Map 3 - modified Satellite Image of Arakwal National Park (Environmental Systems Research Institute 1999)**

## **2.4 Collection Methods**

Collections of aquatic individuals and toadlets begun in the second 6-day round of trapping, Monday 5/1/06. Collections were done in one-hour increments for each type; aquatic and toadlet collections. After each two days of collection the methods would be

switched, aquatic first then toadlets to toadlets first then aquatic. The times of collections were in the afternoon between 12:00 pm and 5:00 pm. Time was kept on a wristwatch.

Toadlet collection involved walking around bodies of water, muddy areas, and clear fields in search of movement. When a toadlet was spotted it was captured by hand and identified, counted, then placed in a bucket with water for storage. If positive cane toad identification could not be made it was returned to the area caught immediately.

The collection of aquatic individuals was done walking around edges of bodies of water and netting schools of toads, using a fine mesh net. Blind nettings, scooping the net through the water without actually seeing tadpoles, were avoided as they rarely yield any cane toad tadpoles in favor of native ones. By focusing on large cane toad groups most bi-catch was avoided. After each netting, the cluster was examined for any native species, which were returned immediately to the water. The tadpoles were then placed in a bucket with water for counting at the end of the survey. Any natives found at this point were returned to the water.

## **2.5 Recording Data**

Data was recorded after each collection or trapping on site in my work journal. The study was conducted beginning with a pilot study on 4/19/2006-4/23/06. The pilot study was a test of setting up the traps and collection methods. No toads were trapped but 51 toadlets and three tadpoles were caught. The actual study began 4/24/06 and continued through 5/13/06. Table 2 gives a layout for the study period.

**Table 2 - Schedule for Study Period**

<b>Week 1</b>	4/24/06-5/1/06	7 nights of trapping, one excluded from study
<b>Week 2</b>	5/1/06-5/7/06	6 nights of trapping and 5 days of collections
<b>Week 3</b>	5/8/06-5/12/06	6 nights of trapping and 5 days of collections

## **2.6 Method Concerns**

This method of changing the trap sites weekly may be of concern. It was done to ensure, from the perspective of the researcher, that the best possible sites were used for trapping. The collections could have been done in quadrats as well, instead of just “following the herd.” As this study aims to find the effectiveness of each method, the best possible scenario was chosen so a real comparison of effectiveness could be made. The best possible scenario for each method usually meant viewing the site that day to see where the tadpoles or toadlets were. Quadrats were also avoided as they are usually considered better for non-moving sampling and it would be difficult to quadrat a changing shore line or a shrinking body of water.

All weather data used was acquired from the Australian Government’s Bureau of Meteorology. The observations used are all from Cape Byron’s automatic weather station. This source was chosen because of recommendation by the National Park Rangers and because this type of equipment was not available to the researcher in the field (Australian Government: Bureau of Meteorology 2006a & b).

After capture each toad was measured to determine which life stage it was in at the time of capture. Anything with a tail still in the water was considered a tadpole. Measurements for metamorphs to adults are done on snout-ischium length (SIL). Metamorphs were any caught between 9 and 29 mm SIL. Over 30 mm SIL would be considered a juvenile. Anything past 89 mm SIL was considered an adult cane toad (Cohen and Alford 1993, p. 1).

## **2.7 Data Analysis**

After determining the life stages and collection of the data in the field, it was then transferred to Microsoft® Excel document for analysis. Based on the focus of the study, to

determine the effectiveness of each method of eradication, a way to compare the results was needed. As each method caught the toads at a different stage in the life cycle, the results would be arbitrary if compared at face value. Figures from a previous study by Lampo and de Leo (1998), giving the probability of survival for the life stages; egg, metamorph, juvenile, and adult, were used.

These survival rates would then be applied to the total caught in each life stage, to determine which method would eradicate the most expected toads. In essence, it was determining what amount of tadpoles or toadlets would survive on to be an adult cane toad so that it could be compared with the trap results. Lampo and de Leo (1998) gave ranges for the expected survival rates of eggs, metamorphs and juveniles. In this study both the low end of the ranges and the high end were calculated.

The range eggs had a survival rate of 68.8% to 73.8% to tadpole. Tadpole to metamorph survival rate used, 1.4% at equilibrium, or in the most likely of circumstances. This figure was used as all other figures for survival of tadpoles included the egg stage. Metamorphs were said to have a 1.2-17.6% chance of survival to the juvenile stage. Juveniles were said to have a 3-7% probability. For this study the egg survival rate to metamorph was used for tadpole as no other figures were available for tadpole survival (Lampo & del Leo 1998 p. 389-392).

From these figures of survival rate from stage to stage, the probability of survival until the adult stage was determined for tadpoles and metamorphs. After combining the survival rates from stage to stage, tadpole survival rate was determined to be from .000504-.0172%. Metamorph survival to adult was calculated to be .036-1.232%. These are the ranges used in converting tadpoles and metamorphs to expected adults for comparison.

After these survival percentages were applied, the mean of each method was calculated along with its variance. The variance is a measure of how broad the distribution is. The variance is calculated with the following formula through Microsoft® Excel's VAR command:

**(/images/variance.jpg)**

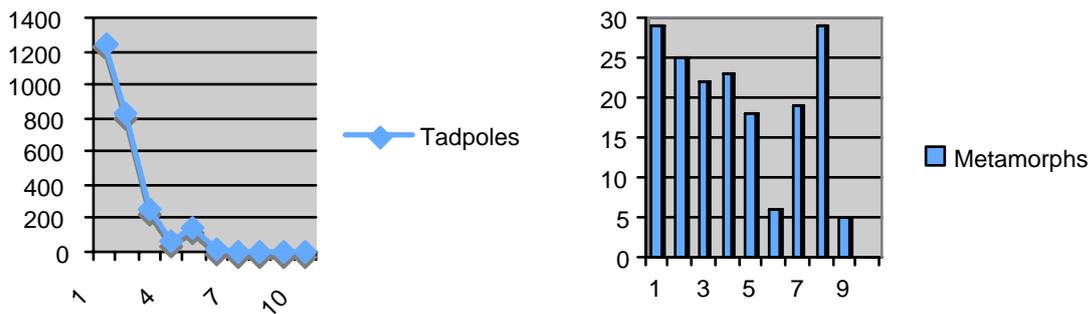
When determining variance one takes each number in the distribution minus the mean of the distribution and then square it and add the results together, dividing by the number of figures in the distribution. The result is the variance which tells us how likely it is that the situation will happen consistently. A variance that is 1:1 with its mean is very likely to occur regularly, where as a variance that is 10:1 to its mean, is a spread out distribution and the figures will occur with scarcity. Variance quantifies the amount of difference between values used in the mean. This is a good way to show which method of eradication will give consistent results, while also showing which will be inconsistent in their effectiveness.

Finally, to compare the methods per hour of labor incurred each total was divided by the amount of collections or trappings. As trappings only took a half of an hour of labor as opposed to the one hour for aquatic individuals and toadlet collections, when comparing, one must note that half as much labor is required for trapping.

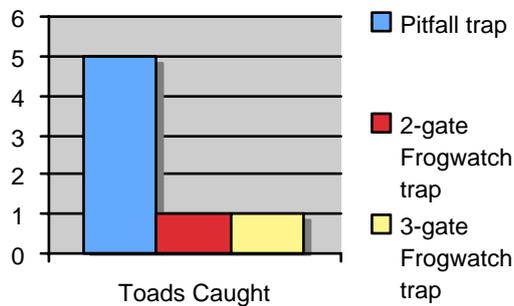
### 3 Results

#### 3.1 Total Catch

After 10 days of collection at 1 hour each day, a total of 2569 tadpoles were caught during the aquatic collection period. No eggs were netted or seen during this time. The average caught per day was 257 tadpoles. The amount of tadpoles that were caught each day varied quite a bit, as Figure 3. During the same 10 days of collection, a total of 176 metamorphs were caught during the toadlet collections. No juvenile or adult frogs were caught or seen during these collections. Each day averaged 18 metamorphs caught; the amount caught each day declined over time seen in Figure 5, as with the tadpoles.

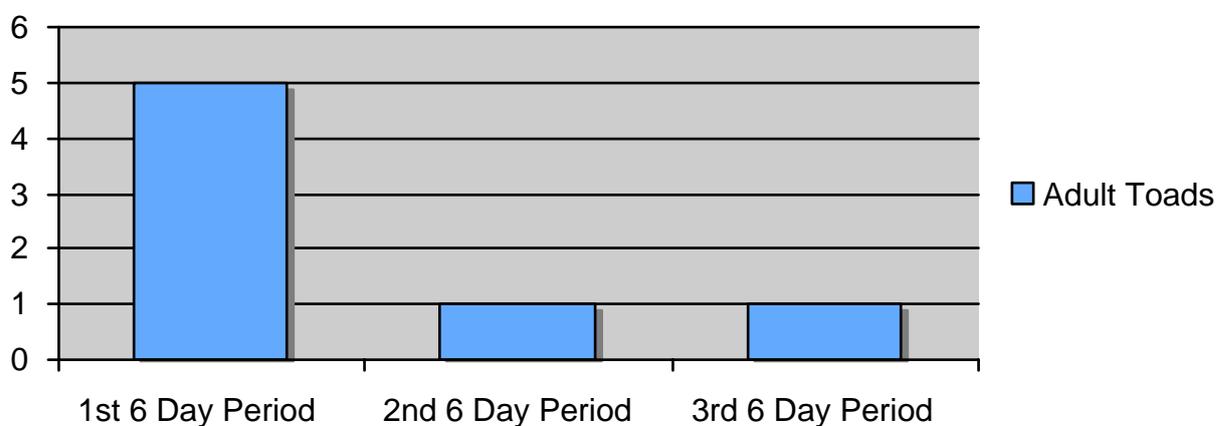


**Figure 3 - Tadpoles caught over ten days    Figure 4 - Metamorphs caught over ten days**



**Figure 5 - Toads caught per trap**

After 18 days of recorded trapping, seven adult cane toads were caught. The mean of this was .39 toads per night by means of all three traps. The variance was calculated at .49. The pitfall trap captured five toads with a mean of .28 toads a night. Both the three-gate and two-gate Frogwatch traps captured one toad in all, with a mean of .06 toads a night each. The comparison between the traps catch can be seen in Figure 5. The amount of toads caught per 6-day period decreased over the three periods as seen in Figure 6.



**Figure 6 - Toads caught per 6-day period**

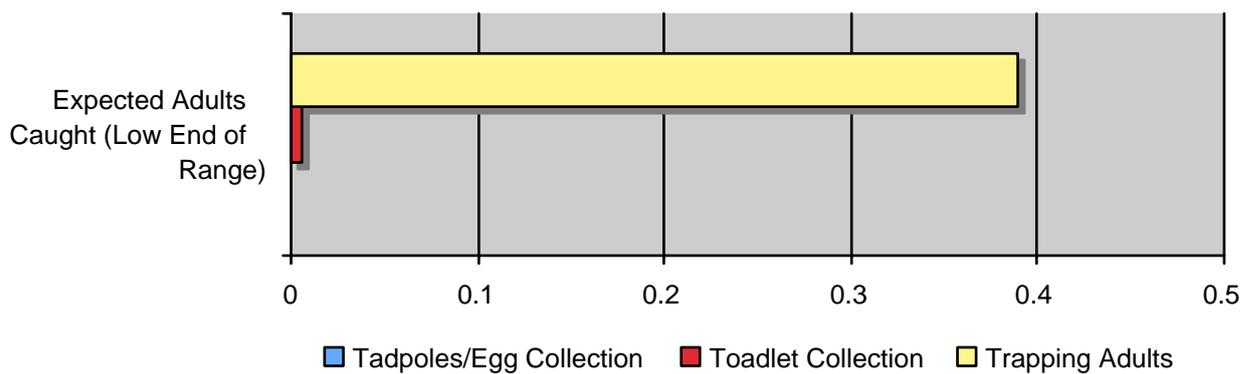
### **3.2 Application of Survival Rates**

When the low ends of the range survival rates were applied to the tadpoles, it was expected that of the 2569 tadpoles caught, .0129 would survive to be adults. The mean of expected adults caught using egg and tadpole collections was then .0013 per hour of collection. The variance was calculated at 1.8589. Of the 176 metamorphs caught, it was expected that .0634 would survive to adult, a mean of .0063 per hour of labor on toadlet collection. The variance was calculated at .0834.

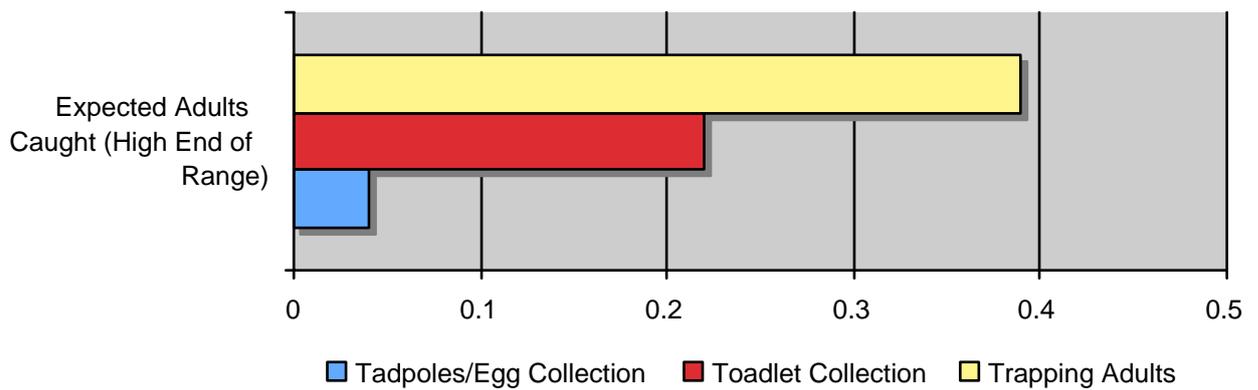
Using the figures for survival from the high end of the range of the tadpoles caught, .44 adult toads were expected to survive to adult. This is a mean of .04 expected adults per

hour of labor in collection. For the metamorphs caught, it was expected that 2.7 adult toads would have been eliminated. This is a mean of .22 toads expected adults per hour of toadlet collection. The variances are the same for high and low ends of the ranges.

Figure 6, shows that many more expected adult toads were caught by the traps on average per hour of labor than any other method when applying the low end of the survival range. Even when the high end of the survival range is applied as in Figure 7, trapping still caught more expected adult individuals than the other methods. One must also note that trapping only required one-half hour of labor as opposed to the hour for collections To account for this, one could assume that double the traps would yield one hours worth of labor.



**Figure 7 - Expected Adults (low end of survival range)**



**Figure 8 - Expected Adults (high end of survival range)**

The variance of the tadpoles collected 1.8589 is around 46 times the mean of .04 in the high end of survival. This indicates a high variance, a high divergence from the mean on a collection-by-collection basis. The variance of the toadlets, .0834 is half times the mean of .22, a smaller variance then for tadpoles. The variance of the adults caught, .49 is around 1.3 times the variance of the mean, .39. The toad trapping shows the least amount of variance, the closest to a 1:1 ratio.

## **4 Discussion**

### **4.1 Most Effective Method**

The results of this study show unequivocally that trapping of adults is the most effective measure of cane toad eradication. The traps, averaging .39 toads for 30 minutes of labor, far exceed the expected adults caught by tadpole collection (.04) and toadlet collection (.22) in one hour's time. This was at the high end of the survival ranges used for tadpole and toadlet calculations. Using the low range of survival probability proved even worse results.

To compare even more fairly one would assume setting six traps as opposed to three would yield the equivalent of 1 hour of labor for trapping. One cannot do more labor in setting the traps, so the amount of traps would need to be doubled to compare with the 1 hour of labor needed for these results with tadpole and toadlet collects.

The low level of variance by trapping proves it is a more assured method, with less sporadic results. On any given night, the mean catch was very likely. The high levels of variance in tadpole and toadlet collection indicate that along with being less effective than trapping they are also less predictable. On any given day of collection the chance of getting the mean catch in this study is very unlikely, with it being much higher or lower.

The fact that the results show that the most successful means of eradication is trapping agrees (with Alford 1995 et Al), where it was concluded that targeting the terrestrial juvenile and adult were the most effective measure. Eradication of adults over metamorphs or tadpoles is even more supported in light of studies that show survival of tadpoles seems to be greater as the density of individuals is less. By capturing tadpoles, it seems, you are actually increasing the chances those left behind will survive on to be adults (Lampo and de Leo 1998). If this were the case collection of tadpoles would be counter productive, causing more likely survival of the remaining individuals to adults. These factors considered

alongside the results that trapping is most effective in overall adult toads eliminated, there seems to be no reason to participate in tadpole collections in an effective eradication scheme.

It must be noted that although toad trapping was most effective in this trial in eliminating expected future adults, the sample size for all stages caught was vary small. Because the amount trapped toads was not very high and the time period this was done in was short, the results are not as steadfast as they could be, a larger scale study is needed to backup these findings, both in amount of traps/collection times and in length of study.

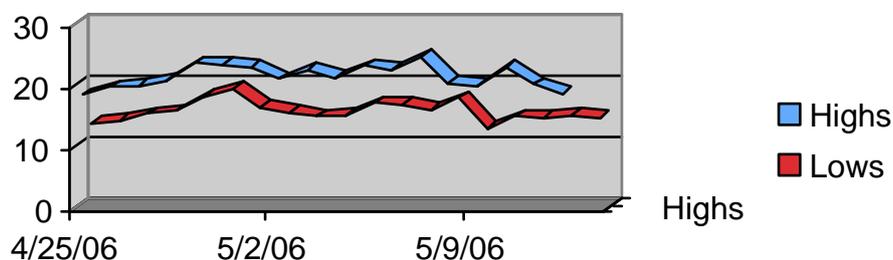
#### **4.2 Depletion of Catch Overtime**

In the results, a striking trend was noticed in the depletion of catch in all three eradication methods over the time period in which they were participated. For the tadpoles, the amount caught was great within the first few days, and then number of individuals caught would slowly decrease both on average and day-by-day. The tadpole depletion seems to be from lack of shallow water. When the site was examined at first, there was no water in the field. Then it rained on 4/16/06 bringing 146.4 mm of rain to the area. After this the field was flooded from the pond to the entrance of the site. The excess rain may have provided a new habitat for the cane toads to breed in and congregate around. As the floodwaters were much shallower then the pond, it may have proved to be a better location for mating. As cane toads have been noted to mate after significant rainstorms this could explain an influx of tadpoles.

As these flood waters receded the water became shallower, and it was at this point that collections begun of tadpoles and metamorphs. Because the water was depleteling day-by-day in the flooded field, tadpole collection was easy as they were forced into smaller and smaller areas. The drop off of tadpoles collected happened at the point all the water in the field was dried up. No tadpoles or metamorphs were then found around or in the pond. Lack

of shallow water could have been the reason for days of zero tadpole catch. The only way in this study to catch the tadpoles was to wade around the edges of shallow areas, and this was not possible at the pond. This seems to suggest that a combination of receding habitat and collections led to the depletion of the tadpole catch day-by-day, until the complete evaporation of the flooded area.

To determine whether the lack of floodwaters led to the decreases in metamorph and adult cane toads caught, one needs to examine other environmental factors as well. One possible explanation for the depletion of the catch could be less activity because of colder temperatures. Looking at the highs and lows in Figure for the time period studied, it does seem probable that the last days' collections of metamorphs could have been affected by the colder temperatures as there seems to be a significant trend over these past few days.



**Figure 9 - Temperatures over study period**

Although the tadpole depletion by collection seems unique, as they are the only life stage limited to a certain sized habitat, it is totally plausible that the collections performed actually depleted the populations of the adults and metamorphs as well. This trend was also seen in trappings by Frogwatch (Sawyer 2005). This can not be asserted, further studies are

need possibly doing a catch and release of toads, marking them to determine re-catch. If the trappings and collections in fact caused the depletion, this alone would be some evidence of effective eradication.

These depletions over time, along with the high variances recorded in tadpole and metamorph collections; suggest that the collections were more effected by outside environmental factors. If this factors can be named by a future study, it is possible that one could increase the catch rate if one choose their collection times and dates better. This could yield more successful collections.

This study also yielded some results which may be useful is designing cane toad traps. During the course of three weeks when the traps were used, two of them, the three-gate FrogWatch trap and the Pitfall trap had light failures. This happened to what were new 8-watt lights on the traps. It appears to have been caused by condensation within the light fixture, both were replaced promptly with 6-watt lights. This was the only thing available at the local store. The lights themselves indicate that they should not be use in wet conditions. It is my suggestion that all traps be equipped with waterproof lamps to avoid future failures.

There was one other night where the light failed to function all night. This was again on the three-gate FrogWatch trap. The wires of the light were chewed through by some animal during the night. I recommend that more heavy insulation is used on the cords to prevent harm to traps and fauna in the future.

## 5 Conclusion

The first aim of this study, to name the most effective method of eradication in Arakwal National Park was met. Trapping of Adult cane toads proved overwhelmingly more successful in cane toad eradication, then any other method tested. After applying survival rates to tadpoles and metamorphs resulting in expected survival to adult, it was determined that targeting the adult cane toad directly was more effective then targeting other life stages. The average of adults, expected or otherwise, caught per day was almost twice as using trapping, then for collection of metamorphs and 10 times higher then for tadpole collections. This was assuming the highest survival rate for tadpoles and metamorphs.

The analysis of variance of each method helped meet the second goal, to identify trends to make the methods as efficient as possible. It shows that trapping is the most reliable method on any given night. The high variance for tadpole collection makes it a hit-or-miss method of eradication. The variance for metamorph was in between these two extremes, much more then trapping but much less then tadpole collection. This high levels of variance, compounded with their little success in catching expected adult cane toads, makes collection methods very ineffective. Recommendations for future study of these trends will be listed later.

The third aim of the study was met by identifying the pitfall trap designed by Mr. Paul Baker, as the most effective trap over the 18 nights on record. The total trapped by the pitfall trap was five adult toads, much higher then the one caught by each of the Frogwatch traps. The fact that all traps were given equal chance and that both Frogwatch traps performed at the same level supports the assertion that the pitfall trap was most successful in trapping adult cane toads.

More reliable lights and power sources would only improve the probability of success for all traps tested. Using solar power coupled with multiple batteries would decrease the labor and chance of failure in future studies. It is also suggested that traps be made more animal proof, to avoid failures resulting from things like chewed power cords. This would benefit both the animals and traps alike.

### **5.1 Recommendation for Future Studies**

A significant decline in the amount of catch over time was observed in this study. There were no control factors to examine this against. It is recommended for future research to investigate the reason for decline. Avoiding a constantly changing area such as the ephemeral wetland used in this study would be one way of testing this. Discovering if the depletion is caused by the removal of the toads themselves would indicate success of the methods involved.

To better understand the high levels of variance in both aquatic and toadlet collections, it is recommended that more studies are done on their behavioral patterns, to determine if there are more successful collection methodologies. A more successful approach to collection may prove that collection methods can be as effective as trapping, although that was not shown here

Future research is also needed to backup the assertions made here, as the sample size was very low, a longer and more intensive study is needed. It is also necessary to examine whether or not the findings made here are season dependent. It is probable that other seasons would have a higher amount of tadpoles and/or toadlets in the environment to be collected. Comparing the findings here with ones done in Queensland where the cane toad is more prolific may yield the evidence needed to backup this claims.

## **5.2 Recommendation for Management**

Based on this study of Arakwal National Park, it is recommended that they only pursue trapping adult cane toads as opposed to other methods of control. As the other methods have been deemed very ineffective in comparison to trapping, the limited labor available to the national park would be better used in setting and clearing of traps. Because the traps function better in clear, short grass areas, it may be useful to conscribe the help of the public in this endeavor. A program for trap placement and care in the neighbors yards near Arakwal National Park maybe a possibility. To limit the overall labor involved in trapping, the use of solar panels to charge the traps batteries as to replacing them manually would save time and effort in the project.

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