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# Potential Flotation Devices for Aerial Delivery of Baits to Brown Treesnakes

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**ABSTRACT:** Brown treesnakes are exotic invasive predators that have extirpated native forest birds and caused drastic reductions of lizards on Guam. Operational management control methods to contain the snake on Guam include the use of live traps, hand capture from fences, and canine detection. Live traps are also used to depopulate small forest plots. Toxicants offer an additional means for reducing snake populations on small plots. Polyvinyl chloride (PVC) plastic pipe bait stations containing dead neonatal mice (DNM) treated with 80 mg acetaminophen are placed about 1.5 m above the ground in vegetation to reduce exposure to terrestrial scavengers such as toads, crabs, and feral pigs. Live traps or bait stations are not practical to use in remote, large-scale areas of forest but aerial delivery of baits may have application. Small plastic parachutes have been used for entangling DNM in forest canopy but parachutes are relatively expensive and cumbersome to use. Inconveniences can be tolerated when only a small number are deployed. But it is anticipated that several thousand baits may be delivered per drop, and inconveniences must be kept to a minimum to maintain an efficient aerial drop system. We therefore evaluated 5 types of flotation materials dropped by helicopter, using DNM implanted with radio transmitters to record landing site (canopy or ground) and bait consumption by snakes and non-target animals. The types of material and percentage of baits that became entangled in the canopy were: paper ring – 39%, paper drinking cup – 50%, excelsior (wood shavings) and burlap – each 56%, and commercial paper food cup – 60%. For all devices, bait consumption by snakes ranged from 19-50% and bait consumption by non-target toads and crabs ranged from 0 - 11%. Commercial food cups were the most convenient material to use because they could be nested together prior to deployment.

**KEY WORDS:** aerial delivery, bait, *Boiga irregularis*, brown treesnake, flotation device, Guam, invasive species, parachute, radiotelemetry, snake

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## INTRODUCTION

It is well documented that brown treesnakes (*Boiga irregularis*) are a major exotic pest species on the island of Guam and have created disastrous ecological effects ranging from the extirpation of 9 of 12 native forest birds to the decline of lizards and Mariana fruit bat (*Pteropus mariannus*) populations (Rodda and Fritts 1992a; Rodda et al. 1999a; Savidge 1984, 1987; Wiles 1987a, 1987b). The snakes probably arrived on Guam in the late 1940s as stowaways in cargo from the Admiralty Islands, about 1,500 km south of Guam (Fritts 1987, 1988; Rodda et al. 1992). Lacking natural predators, their range expanded to encompass the entire island, and populations irrupted with as many as 50-100 snakes per hectare in some areas (Rodda and Fritts 1992b, Rodda et al. 1999b). Brown treesnakes also cause power outages, are an agricultural pest that prey on poultry, and although only mildly venomous, their bites can be life threatening to small children (Fritts et al. 1987; Fritts and McCoid 1991; Fritts et al. 1990, 1994). Guam is a major trans-Pacific shipping hub and there is concern that snakes could spread to snake-free areas with similar effects on the ecology and economy. There have been confirmed brown treesnake sightings in Hawaii, the Commonwealth of the Northern Marianas Islands, and southern United States, but there is no evidence that snakes have established populations at these locations (Fritts 1987, 1988; McCoid et al. 1994). Operational efforts to thwart the inadvertent dispersal of snakes from Guam were initiated in 1993 by the U.S. Department of Agriculture – Wildlife Services, using a variety of techniques including trapping, search dogs, and hand capture from fences during nighttime spotlight searches (U.S. Dept. of Agriculture 1996). These methods, however, are primarily for local, small-scale control and would not be practical to use over large geographic areas of habitat needed for the reintroduction of endangered species (BTSCC 1996).

The National Wildlife Research Center developed an oral toxicant for brown treesnakes (U.S. EPA Reg. No.56228-34) and it has potential to be used in large, inaccessible landscape areas. Bait stations containing dead mice treated with 80 mg acetaminophen are effective for reducing snake populations in small 5-7 ha plots of accessible jungle forest (Savarie et al. 2001), but a practical system for delivery of baits to remote areas of jungle is not available. Small plastic parachutes (Shivik et al. 2002) and cornstarch paper spiral streamers dropped from a helicopter have been used as flotation devices for entangling mice in the forest canopy away from potential terrestrial scavengers such as coconut crabs (*Birgus latro*), land hermit crabs (*Coenobita* spp.), marine toads (*Bufo marinus*), and wild pigs (*Sus scrofa*). It is tedious to attach the flotation devices to mice and cumbersome to deliver the devices when inconveniences inherent to the devices are encountered. For instance, the plastic parachute has 6 thread-size stringers that often become tangled; and when cornstarch paper streamers are removed from the freezer prior to aerial drop, the high humidity on Guam causes condensation on the paper and the paper streamers stick to themselves. These inconveniences can be tolerated when a small number of devices are used (24 parachutes with baits were used at one time by Shivik et al., and 225 was the maximum number of cornstarch paper spiral devices used per bait drop, 20 of them with radiotransmitters, L. Clark, pers. commun.). However, it is anticipated that several thousand aerial baits may be delivered per drop and inconveniences must be kept to a minimum so that the aerial drop system becomes as efficient as possible. The present study was designed to evaluate flotation materials that would be more convenient to use. Additionally, only biodegradable materials were tested to reduce the potential accumulation of litter in the forest.

## METHODS

In August 2003, we used aerial drop procedures and tracts of land similar to those described by Shivik et al. (2002) for evaluating flotation materials attached to untreated dead neonatal mouse (DNM) baits. Five tracts of land (each approximately 400 × 50 m) were selected adjacent to Tarague Beach road on Andersen Air Force Base, Guam. DNM baits were attached to flotation materials by a 30-cm thread secured to a rear leg of the mouse. Five types of biodegradable flotation materials, all spray-painted fluorescent orange to highlight their visibility in the vegetation, were evaluated: paper ring (cut from a paper towel tube), 2.5-oz paper cup, excelsior (wood shavings), burlap, and paper food cup. DNM weighed about 5 g each and were implanted with 1.9-g radiotransmitters measuring 1.9 × 0.7 cm with a 10.2-cm whip antenna (Model F1620, Advanced Telemetry Systems, Isanti, MN). Radiotransmitters were inserted into the body cavity of the mice and held in place with a thread tie. Only one type of flotation material was dropped on each of the five tracts of land, and 20 DNM baits were deployed for each aerial drop. The day before baits were deployed, they were fitted with radiotransmitters and flotation material and were placed in a freezer overnight. The baits were thawed for 2 - 3 hr before being hand dropped from approximately 30 m above the ground from a Sikorsky MH-60S Black Hawk helicopter.

We monitored the baits with radiotelemetry immediately after aerial drop to determine their location (height in the canopy or on the ground). Not all baits in the canopy could be visually located and height in the canopy was determined only from those we could see. Baits that could not be located or baits that separated from their radiotransmitters during the drop were deleted from the data set. Since our primary goal was to assess the performance of the flotation materials, we only determined if baits were consumed during the first night. Baits that were not consumed were collected and the radiotransmitters recovered for re-use. Snakes that consumed baits were tracked, captured when logistically feasible, euthanized, and the radiotransmitters recovered. A radiotransmitter without the presence of the mouse bait was classified as an unknown bait-take. Captured snakes were weighed, sexed, and snout-vent length measured. Marine toads that consumed baits were captured, placed in cages until they expelled the radio-transmitters, and then released at the study site.

## RESULTS

Results for entanglement in the canopy and bait-take by brown treesnakes and non-target animals for each of the 5 flotation materials are summarized in Table 1. Additional data specific for each type of material are presented below.

### Paper Ring

Two radios found on the ground after the drop were separated from the baits, which were never located. Seven baits were tangled in the canopy and 11 landed on the ground. The mean height of 6 baits in the canopy was 2.6 m. During the first night, snakes took 4 of the 7 baits from the canopy and 3 of the 11 from the ground. Three transmitters were found on the ground but the baits were missing and classified as unknown bait-takes. One bait with a radio was found on the ground after being detached from the paper ring in the canopy.

### Paper Cup

One radio was found on the ground disassociated from the bait and 3 baits were not found until the day after the drop, so these are not included in the data summary. Eight baits were in the canopy and 8 were on the ground. Five baits in the canopy had a mean height of 1.3 m. Two of 8 baits in the canopy and 1 of 8 baits on the ground were taken by snakes. One string detached from the paper cup in the canopy and the bait and radio were found on the ground.

### Excelsior

Two radios were on the ground after the drop detached from baits that were never found. Ten baits were in the canopy and 8 baits were on the ground. Mean height of 7 baits in the canopy was 1 m. Snakes took 4 of the 8 baits in the canopy but none from the ground. Marine toads took 2 of the ground baits. There were 2

**Table 1. Summary of the aerial drops with 5 flotation materials.**

| Flotation Material | % Entangled in Canopy | % Bait Taken | | | | % BTS Bait Taken From: | |
|---|---|---|---|---|---|---|---|
| | | BTS | Toad | Crabs | Unknown | Canopy | Ground |
| Paper Ring (*n* = 18) | 39 | 39 | 0 | 0 | 17 | 57 | 27 |
| Paper Cup (*n* = 16) | 50 | 19 | 6 | 6 | 0 | 25 | 12 |
| Excelsior (*n* = 18) | 56 | 22 | 11 | 0 | 11 | 40 | 0 |
| Burlap (*n* = 18) | 56 | 50 | 0 | 0 | 0 | 40 | 62 |
| Food Cup (*n* = 20) | 60 | 50 | 5 | 0 | 15 | 67 | 25 |
| Average | **52** | **37** | **4** | **1** | **9** | **47** | **26** |

unknown bait-takes, 1 in the canopy and 1 on the ground. One bait became detached from the excelsior in the canopy and was found on the ground with its radio.

**Burlap**

One radio signal was lost and 1 bait was cut in half, probably from striking a sharp limb or leaf during the drop. Ten baits landed in the canopy (mean height of 2.3 m) and 8 baits were on the ground. Four of the 10 baits in the canopy and 5 of the 8 ground baits were taken by snakes. One snake took 2 baits, 1 from the canopy and 1 from the ground.

**Food Cup**

Twelve baits landed in the canopy and 8 landed on the ground. Mean height of 8 baits in the canopy was 1.9 m. Snake bait-take was 8 of 12 in the canopy and 2 of 8 from the ground. One marine toad took a bait that landed in the canopy but presumably fell to the ground where the toad consumed it. There were 3 unknown bait-takes from the ground.

**Snake Morphology**

Thirteen (5 males, 8 females) of the 32 snakes that consumed baits were captured and radiotransmitters recovered. The mean body weight was 84.2 g, SE = 8.3, range = 56.2 - 147.8 g, and the mean snout-vent length was 905.8 mm, SE = 19.8, range = 821 - 1037 mm. These snakes are in the same size class as described in the previous aerial study (Shivik et al. 2002).

Results for 2 non-biodegradable and 6 biodegradable flotation materials entangled in the canopy are summarized in Table 2. The materials are listed in order of increasing diameter and it is apparent that physical dimensions contribute to their entanglement in the canopy. As the diameter for the materials with single thread attachment to the mouse bait increases, there is a general trend corresponding to an increase of captures in the canopy. The highest entanglement was with the plastic parachute (92%) and it had the biggest diameter plus 7 threads (6 thread risers on the parachute connected to a thread that attached to the bait).

**DISCUSSION**

Research using untreated (Shivik et al. 2002) and acetaminophen-treated dead mice (L. Clark, pers. commun.) has shown that aerial distribution is a feasible method for delivering baits to snakes. It is important to emphasize that the major objective for the present study was to assess entanglement of baits with flotation materials in the vegetation. Since we determined bait-take only after the first night, consumption of baits by brown treesnakes and non-target animals is biased on the low side. The second night (48 hr) is usually the optimum field exposure time for maximum dead mouse carrion bait consumption by snakes (Shivik and Clark, 1997, Jojola-Elverum et al. 2001). Bait-take from the canopy and ground after the first night ranged from 19-50% by snakes and 0-11% by non-targets for each of the 5 aerial applications we conducted (Table 1). For each of two aerial drops reported in Shivik et al. (2002), the first night bait consumption by snakes was 16% and 58%, with an overall bait-take of 32% and 63%; overall non-target bait-take was 5% and 0%.

**Table 2. Diameter and performance of flotation devices evaluated for bait delivery.**

| Material | Diameter (cm) | *n* | % In Canopy |
|---|---|---|---|
| Plastic streamer[1,2] | 3.0 | 20 | 42 |
| Paper ring | 4.4 | 18 | 39 |
| Paper cup (2.5oz) | 5.5 | 16 | 50 |
| Excelsior, wood shavings | 7.0 | 18 | 56 |
| Food cup | 11.0 | 20 | 60 |
| Paper spiral[3,4] | 15.0 | 79 | 42 |
| Burlap | 18.0 | 20 | 56 |
| Plastic parachute[1,5] | 26.5 | 24 | 92 |

[1] Shivik et al. 2002 (evaluated August 2001). These materials are non-biodegradable.
[2] 60-cm long single loop of plastic flagging.
[3] L. Clark, pers. commun. (evaluated August 2002).
[4] Spiral cut from 15 cm square cornstarch paper. As spiral falls through the air the diameter is substantially less than 15 cm
[5] Parachute has 6 thread-like stringers attached to a single thread that is attached to mouse.

The overall non-target bait-take by crabs and marine toads was 1% and 4%, respectively, and 9% of the baits became separated from the transmitter and their disposition could not be determined (Table 1). The disassociation of transmitters from the baits may have resulted from non-targets (e.g., crabs) consuming the bait piecemeal, or expulsion of the transmitters when snakes constrict baits during swallowing. The greatest detriment of non-targets such as crabs and toads taking baits is that the baits would not be available for the brown treesnakes, and proportionately more baits would have to be delivered to effectively control the snakes.

Presently there are two areas on Guam, both located on Andersen Air Force Base, that represent a high risk of exposing endangered birds, Micronesian starlings (*Aplonis opacus guami*) and Mariana crows (*Corvus kubaryi*), to aerially applied baits. To avoid potential exposure, it would be prudent to use bait stations in these habitats to exclude birds from getting baits (Avery et al. 2004). The majority of the island of Guam does not have sensitive areas in regards to wildlife and aerial application would seem appropriate, especially in remote, inaccessible cliff line and forest areas.

Despite the proven applicability of aerial bait delivery (Shivik et al. 2002; L. Clark, pers. commun., this study) more effective aerial delivery systems are needed. From an environmental standpoint neither the plastic streamer nor parachute are acceptable materials because some were found intact 2 years after they were dropped in the forest. The paper spiral was cut from cornstarch paper similar in composition to starch biodegradable packaging peanuts and is highly water soluble and compostable. The paper spirals were routinely dissolved by rain, leaving no trace except for the cotton thread. It is also expected that the five materials evaluated in this study would degrade in the forest but these data are not available. Threads on the flotation devices often tangled, and during the paper ring drop, three knotted together and landed on the ground. The most user-friendly device we evaluated was the food cup because cups could be nested together.

A complete aerial bait delivery system will involve several matched components including the type of aircraft (fixed wing or helicopter), methodology to conveniently lace treated baits and attach them to biodegradable flotation material, and automated equipment for bait deployment from the aircraft. Research is underway to develop an efficient aerial bait system that can be used for large-scale application to brown treesnakes.


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