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Evaluating commercially available rodenticide baits for invasive Gambian giant pouched rats (*Cricetomys gambianus*)

Gary W. Witmer*, Nathan P. Snow, Patrick W. Burke [1]

USDA/APHIS Wildlife Services, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521-2154, USA

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ABSTRACT

Gambian giant pouched rats (*Cricetomys gambianus*) are native to Africa, but they are popular in the pet industry in the United States. They were reservoir hosts during a monkeypox outbreak in the Midwestern United States in 2003. A free-ranging population became established on Grassy Key in the Florida Keys, apparently because of a release by a pet breeder. These rodents could cause significant damage to agricultural crops should they reach the mainland. Research under controlled conditions was needed to identify effective rodenticides for Grassy Key or other cases where an invasion of Gambian rats might occur. We tested 2 formulations of diphacinone baits and 1 formulation each of brodifacoum, zinc phosphide, bromethalin, and chlorophacinone baits with captive Gambian rats in multiple-choice food trials. Both the brodifacoum and zinc phosphide rodenticide baits were highly effective (100% mortality). Also, brodifacoum and zinc phosphide treatments performed similar to the Environmental Protection Agency's standard for toxicants of (i.e., 90% mortality in laboratory trials). The chlorophacinone, diphacinone, and bromethalin baits did not appear to be very effective at killing Gambian rats ($\leq$50% mortality) in our study. Effective tools to combat Gambian giant pouched rats have been identified in a laboratory trial. Further field testing of commercially available brodifacoum and zinc phosphide baits may prove useful for controlling the potentially invading Gambian rats.

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1. Introduction

Introduced rodents pose a serious threat to the native flora and fauna of islands (Howald et al., 2007). Rodents can be very prolific on islands where they have few, if any, predators, and their omnivorous foraging has lead to the endangerment or extinction of numerous island species (Witmer et al., 1998). Most seabirds that nest on islands have not evolved in the presence of sympatric predators and are, therefore, very vulnerable to introduced rodents and other species introductions. There has been a concerted worldwide effort to eradicate introduced rodents from islands with numerous successes (Howald et al., 2007; Moors and Atkinson, 1984). These efforts have relied heavily on the use of various rodenticides (Howald et al., 2007; Witmer et al., 2007).

Gambian giant pouched rats (*Cricetomys gambianus* Waterhouse) have become established on Grassy Key in the Florida Keys (Perry et al., 2006). These rodents are native to a large area of central and southern Africa (Kingdon, 1974) and because of their large size (2.8 kg; 1 m length), they are used as a high-protein food source (Ajayi, 1975). Gambian rats are omnivorous; and in their native range they consume vegetables, insects, crabs, snails, palm fruits, and palm kernels (Ajayi, 1975). Although no food-habit studies have been conducted for the free-ranging Gambian rats on Grassy Key, the region contains many dietary options for Gambian rats, both native and non-native. For example, some plants available are Australian pine (*Casuarina equisetifolia* L.), Brazilian pepper trees (*Schinus terebinthifolius* Raddi), sea grape shrubs (*Coccoloba uvifera* L.), and papaya (*Carica papaya* L.; Long and Lakela, 1971; FNAI, 1990). Other examples of likely food sources are tree snails (*Drymaeus multilineatus* Albers; Townsend et al., 2005), land crabs (*Cardisoma guanhumi* Latreille; Gifford, 1962), and eggs of various nesting birds (Jewell, 2002).

Gambian rats are known to cause substantial losses to food crops in Africa (Fiedler, 1988). There is a concern that this species could cause substantial agriculture damage if it were to reach the mainland USA and become established (Peterson et al., 2006). Additionally, there is also a concern about this species posing a disease threat as they have been known to carry monkeypox and

* Corresponding author. Tel.: +1 970 266 6335; fax: +1 970 266 6089.
E-mail address: gary.w.witmer@aphis.usda.gov (G.W. Witmer).
[1] Present address: Wyoming Department of Game and Fish, 351 Astle, Green River, WY 82935, USA.

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various other diseases transmissible to humans and livestock (Perry et al., 2006; Fiedler, 1988). There was an outbreak of monkeypox in the Midwestern USA in 1993 that was linked to infected Gambian rats that had been brought into the country for the exotic pet industry (Centers for Disease Control and Prevention, 2003). This was the first monkeypox outbreak in the western hemisphere (Enserink, 2003). Fortunately, a sample from the free-ranging Gambian rat population on Grassy Key was found to be seronegative for monkeypox by the Centers for Disease Control and Prevention (Perry et al., 2006). Preliminary work with the Grassy Key invasive rodent population (monitoring, preliminary rodenticide testing) was presented (Engeman et al., 2006) and an eradication strategy was designed and implemented in 2007. Initially, a 2% zinc phosphide rodenticide bait (with the active ingredient mixed with peanut butter, grains, and molasses) was used because a preliminary trial on Grassy Key with a few Gambian rats suggested that it would be effective (Engeman et al., 2007). The rodenticide bait was placed in a grid of bait stations across the entire island. The eradication effort is continuing, but there were difficulties in achieving success (Engeman et al., 2007). Hence, additional effective rodenticide baits are needed to control and eradicate introduced Gambian giant pouched rats. Although many commercial rodenticide baits are registered by the United States Environmental Protection Agency (EPA) for commensal rodent control (Witmer and Eisemann, 2007), none were registered for Gambian rats and we found no evidence of any testing of rodenticides for efficacy with Gambian rats. We chose to test commercial rodenticides already available in the USA and already registered by the EPA for commensal rodents because we knew that managers could more readily obtain a new registration for use of these materials on the invasive Gambian rats as long as they were proven to be efficacious on that species. Even in Africa, few rodenticides are available or used and there has been little efficacy testing (Fiedler, 1994).

We used a standardized efficacy protocol (e.g., Schneider, 1982) under indoor, controlled conditions. Because free-ranging rodents usually have numerous food items available to them, it is important that rodenticide baits be attractive and palatable, as well as efficacious when presented with an alternative food type. We tested the efficacy of six commercially available rodenticide baits on captive, wild-caught Gambian rats from the Florida Keys. We hypothesized that one or more of the test rodenticides would be consumed and highly efficacious ($\geq$80% mortality) when presented with alternative food types (i.e., multiple-choice efficacy trial).

2. Methods

In our trials, we only used free-ranging Gambian rats live-trapped on Grassy Key, Florida, or the first-generation offspring of those animals to make inference to the population on Grassy Key. We housed the captured rats and any subsequent offspring in metal rack cages at the Invasive Species Research Building of the United States Department of Agriculture's (USDA) National Wildlife Research Center (NWRC) in Fort Collins, Colorado. The Gambian rats were held in individual cages, measuring $60 \times 50 \times 45$ cm (Allentown Caging Equipment Co., Allentown, NJ). The Gambian rats were allowed several weeks to acclimate to the room, cages, and foods before the trial began. Animals were fed a maintenance diet consisting of a rodent pelleted chow (Lab Diet 5008, PMI Nutrition International LLC, Brentwood, MO) supplemented with nuts and fruit. Gambian rats are known to feed on fruit and nuts in their native range (Ajayi, 1975). While we did not monitor the amount of maintenance diet consumed by test animals, the diet was well accepted and all rats maintained or even gained weight during the study.

The rodenticides we tested had varying amounts of active ingredients, but all are currently registered for use with commensal rodents. We randomly assigned 6 Gambian rats to each treatment group. The treatments included baits containing one of the following: 2.0% zinc phosphide on oats (Zinc Phosphide on Oats, USDA Animal Plant and Health Inspection Service, Riverdale, MD), 0.0025% brodifacoum pellets (CI-25 pellets, Bell Laboratories, Inc., Madison, WI), 0.005% chlorophacinone pellets (Rozol Pellets, Liphatech, Inc., Milwaukee, WI), 0.01% bromethalin blocks (Fastrac Blox, Bell Laboratories, Inc., Madison, WI), 0.005% diphacinone pellets (Ramik Green, HACCO, Madison, WI) or 0.005% diphacinone blocks (Ramik Mini Bars, HACCO, Madison, WI). The control group was fed only the maintenance diet. The treatment groups of Gambian rats also received the maintenance diet throughout the trial. The maintenance diet was replenished daily. All rats were at least 6 months of age (i.e., sexually mature) at the beginning of the study. Each group of rats contained both sexes, but the ratio varied because of the actual number of females and males available for the study. We compared the average weights of Gambian rats among each group with an analysis of variance (ANOVA; Proc GLM, SAS Institute, Cary, NC).

On day 1 of the 7-day, multiple-choice feeding trial we added the respective rodenticide baits along with maintenance diet. We placed 100 g of the appropriate rodenticide bait into the cage inside a ceramic bowl. For the rodenticide blocks (diphacinone and bromethalin), we initially added two of the blocks (44–56 g), because additional blocks could readily be inserted into the cages later, as needed. Rodenticide baits and maintenance foods were replenished as needed (based on a visual observation each day of the amounts remaining) so that rats always had all types of provisions available. Rodenticide bait consumption was monitored by weighing the initial bait when the trial began and any bait that was replenished, then we subtracted the weights of any bait that accumulated below the cages and any bait that remaining in the cage after the seventh day (end of rodenticide exposure period). All rodenticide baits were removed at the end of the seventh day and surviving rats were put into clean cages and were fed the maintenance diet. We compared the average proportions of rodenticide baits consumed among the treatment types with an analysis of variance (ANOVA; Proc GLM, SAS Institute, Cary, NC).

All rats were examined daily and the condition of the rats and any mortality was recorded. We conducted necropsies on all rats, during which time we recorded weight and any signs of anticoagulant poisoning for the anticoagulant rodenticides (Stone et al., 1999). Rats that remained alive after the trial were observed for another 10 days, then were euthanized and necropsied as described above. Any mortality that occurred in that 10 day period was recorded. We compared the average weights of rats within each treatment group with an ANOVA (Proc GLM, SAS Institute, Cary, NC). After necropsy, all carcasses from the study were incinerated at NWRC.

The EPA standard for desired efficacy of rodenticide baits in a laboratory trial is 90% mortality (Schneider, 1982). We compared the efficacy of each treatment type to the EPA standard using Fisher's Exact, chi-squared tests (Proc Freq, SAS Institute, Cary, NC).

3. Results

The mean weights of Gambian rats among the various treatment types did not vary ($F_{32} = 0.90$, $P = 0.349$). The percent of total bait consumed among treatment types did significantly differ ($F_{33} = 6.22$, $P = 0.018$; Table 1). The treatment types tested had varying degrees of efficacy for poisoning Gambian rats (Table 1). The zinc phosphide and brodifacoum baits were highly efficacious (100% mortality) and only a small amount of the bait needed to be