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THE PATH TO ERADICATION OF THE GAMBIAN GIANT POUCHED RAT IN FLORIDA

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Abstract: A thriving population of Gambian giant pouched rats became established on Grassy Key, a 550-ha island in Florida, following escape(s) from an exotic pet breeder. After existence of the population was verified, computer models indicated that Gambian giant pouched rats could successfully invade a large portion of North America if they reached the mainland. This largest of rat species is highly prolific, and its dispersal to the mainland could result in substantial negative impacts to agriculture, environment, and wildlife. Additionally, Gambian giant pouched rats are known vectors of a variety of diseases transmissible to humans and livestock. The first action to counter the severe and immediate threat of dispersal was to rapidly develop the information necessary on which to base an eradication program. The information included detection and monitoring technologies, population indexing methodologies, population distribution, habitat preferences, trapping methodology, acceptance of bait matrices, and efficacy tests of toxicants, and bait stations that minimize exposure to native species. With these tools forming a foundation, a pilot eradication was funded for Crawl Key, a 150-ha key adjoining Grassy Key to which the species expanded its range. The aims of the pilot eradication were to test and fine-tune the methods prior to implementing full-scale eradication on Grassy Key. No Gambian giant pouched rats were found in two subsequent surveys of Crawl Key. Further surveys of Grassy Key were used to refine bait station densities for the full scale eradication effort implemented on Grassy Key in spring 2007. The eradication effort is on-going.

Key Words: bait station, *Cricetomys gambianus*, eradication, Florida Keys, Gambian giant pouched rat, invasive species, monitoring, rodenticide.

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INTRODUCTION

Breeding populations of non-native vertebrate species are regularly identified in Florida. In fact, Florida, along with Hawaii, have the most severe invasive species problems in the United States (US Congress 1993). The negative impacts inflicted by exotic species on native species and ecosystems might be exceeded only by human-caused habitat destruction (Wilcove et al. 1998, Parker et al. 1999). The impacts from many introduced species are unknown or not readily perceived by the public. The realization of an introduced species' existence, and perhaps even its potential for severe impacts, may not occur until after the species has been established for some time. Such was the case with the Gambian giant pouched rat (*Cricetomys gambianus*) in Florida.

Eight Gambian giant pouched rats apparently escaped from an exotic pet breeder on Grassy Key, Florida around 1999 (Perry et al. 2006). A local resident brought the Florida population to the attention of authorities after media reports had associated Gambian giant pouched rats in the US pet trade with an outbreak of monkeypox (Centers for Disease Control 2003). Unconfirmed sightings suggested possible dispersal to other Keys.

The Gambian giant pouched rat had the potential to become a highly destructive exotic species in the United States (US), particularly in agriculture. The species is among the largest members of the rat family *Muridae*, with males achieving weights as high as 2.8 kg (Rosevear 1969). They are omnivorous, consuming a variety of vegetables and fruits, insects, crabs, and snails

(Ajayi 1975, Smithers 1983, Fiedler 1988, Fiedler 1994). Gambian giant pouched rats are also highly fecund, with gestation times ranging from 27-42 days and 4-5 litters/year of 1-5 offspring (Rosevear 1969, Ajayi 1975, Hayssen et al. 1993). In an African agricultural setting, 42 Gambian giant pouched rats were removed from a 0.2 ha field of young peas in Zimbabwe (Smithers 1983, Fiedler 1994). Besides monkeypox, members of this genus have been linked to potentially pathogenic zoonoses such as leptospirosis, bartonellosis, murine typhus, Q-fever and trypanasomiasis (Gretillat et al. 1981, Fiedler 1988, Hutin et al. 2001, Herder et al. 2002, Machang'u et al, 2004),

The Gambian rats large size, high fecundity, omnivorous diet, and potential as vectors of serious diseases made this species an immediate threat to the indigenous ecological communities and human interests within the Florida Keys. Moreover, ecological modeling demonstrated that Gambian giant pouched rats could invade and establish viable populations throughout Peninsular Florida, the US Gulf Coast, and beyond to Central America (Peterson et. al. 2006). Wider areas of North America were also shown to be vulnerable to Gambian giant pouched rat population establishment at lesser probabilities.

Recognition of an invasive species as a severe threat to natural ecosystems, agriculture, and human health and safety does not ensure that an eradication program will take place, nor that such a program once implemented would be successful. A successful eradication effort requires development of pertinent information, appropriate techniques, and the political will (including funding) to proceed effectively. Here, we describe this path culminating in an eradication effort for Gambian giant pouched rats in Florida (US), and the status of that effort as of September 2007.

IN THE BEGINNING

Until the monkeypox outbreak, Gambian giant pouched rats were popular animals in the pet trade. Like many other species, they were captive-bred in Florida (many of these other species have also successfully established breeding populations in Florida). As already indicated, escapees from a pet breeder on Grassy Key formed the foundation for a burgeoning population. Without notification of their existence, one can only speculate how long the population would have existed, grown, and spread before action was taken, and whether that action would have been in time to prevent their dispersal to the mainland.

The initial step towards eradicating Gambian giant pouched rats was to confirm the existence of a breeding population, which was carried out by a graduate student from Texas A&M University already in the area researching Lower Keys marsh rabbits (*Sylvilagus palustris hefneri*) (Perry et al. 2006). The population's existence prompted the already mentioned computer modeling that projected wide dispersal on the continent if the species reached the mainland (Peterson et al. 2006).

GATHERING INFORMATION, DEVELOPING TECHNOLOGIES AND STRATEGIES

Once a Gambian giant pouched rat population was confirmed as established, the next step towards addressing the Gambian giant pouched rat population was to generate information in areas essential for commencing an eradication program: (1) methods to detect and monitor populations, (2) distribution, (3) habitat preferences, (4) development of control methods, and (5) influence of non-target species on detection and management.

Detecting and Monitoring Gambian Giant Pouched Rats

Having a rapid means to detect and survey Gambian giant pouched rats was essential for monitoring distribution and relative abundance. Several existing methods were tested for their ability to detect the presence of Gambian giant pouched rats, including live trapping, remote digital cameras and tracking tiles. Cameras and tracking tiles served well to detect Gambian giant pouched rats while also accommodating large numbers of nontarget species. Simultaneous monitoring of non-target species was an important consideration, as this would provide valuable information for assessing and reducing non-target hazards from control methods, and for reducing non-target interference with control technologies. Both cameras and tracking tiles were also suitable for field application, and produced data appropriate for use in a general indexing paradigm whereby populations could be monitored in a statistically valid fashion (Engeman 2005).

Although the track plate materials and methodology were developed to most efficiently record tracks with a minimum of resources, the method was still substantially more labor-intensive than using remote digital cameras. Therefore, track

plates were considered for operational application only in situations where the risk of theft or vandalism was too great for deploying cameras (Engeman et al. 2006). Motion-triggered digital cameras served particularly well to detect Gambian giant pouched rats while providing data suitable for monitoring abundance. Digital cameras could record a large number of visits, with batteries usually lasting 3-4 days. Their ability to record Gambian giant pouched rats was not hindered by non-target species saturation at camera stations. Cameras also provided a reliable tool to evaluate control efficacy, detect varying Gambian giant pouched rat abundances throughout Grassy Key, and optimize of timing and placement of control devices in a fashion similar to the strategies that greatly improved control efficacy and efficiency for managing predators of sea turtle nests (Engeman et al. 2003, Engeman et al. 2005). Camera surveys also verified Gambian giant pouched rat survival on Grassy Key in the wake of highly destructive Hurricane Wilma. Although much of Grassy Key was inundated by more than 1 m of salt water from the storm surge, the continued presence of Gambian giant pouched rats was readily demonstrated.

Trapping was applied to address multiple needs: (1) detect the presence of Gambian giant pouched rats, (2) refine the information on their distribution, (3) refine trapping techniques including bait and trap placement, and (4) evaluate its impacts to and from non-target species. Gambian giant pouched rats were relatively easily captured using raccoon-sized cage traps baited with peanut butter and/or fruit. However, relative to the numbers of Gambian giant pouched rats captured, large numbers of non-target animals were captured, primarily raccoons (*Procyon lotor*), but also Virginia opossums (*Didelphis virginiana*), black rats (*Rattus rattus*), and the occasional feral cat (*Felis silvestris catus*). About five and a half times as many non-target animals were captured as Gambian giant pouched rats. Thus, non-target trap saturation impaired Gambian giant pouched rat trapping efficiency (Engeman et al. 2006). Also, Gambian giant pouched rats were not captured in traps that had previously captured a raccoon without a thorough cleansing, which could be an important consideration for future trapping efforts, but previous capture of a Gambian giant pouched rat did not appear to affect results (Engeman et al. 2006). A similar effect was documented in Hawaii where black rats avoided traps that had previously captured a mongoose (Tobin et al. 1994).

Distribution and Habitat Preferences

Multiple detection and survey methods were applied to identify the Gambian giant pouched rat distribution among the keys. Islands with unconfirmed reports of sightings were a priority for surveillance. Many of the unconfirmed sightings occurred on neighboring Keys. Although originally separated by saltwater, a series of earth-filled causeways connects Grassy Key to its neighbors to the west, whereas an 11-km bridge connects it to neighboring Keys to the east. Thus, keys nearby Grassy Key were also the focus of surveys, as were the islands involved in the transfer of trash and hurricane debris from Grassy Key. The short distances to neighboring keys, especially those connected to Grassy Key by the earth-filled causeways provide access for Gambian giant pouched rats to move to new islands, whereas refuse hauling could offer ready, but inadvertent, human-aided transport to other keys and mainland. Thus, the vicinity of the transfer station on Long Key (11 km east of Grassy Key) where Grassy Key trash collection is transported was surveyed by multiple methods, as was the site on Knights Key (5 km west of Grassy Key) where debris from Grassy Key following Hurricane Wilma was piled for later transfer (Engeman et al. 2006).

Outside of Grassy Key, Gambian giant pouched rats were found only on Crawl Key, the first key west of Grassy Key, and thereby demonstrating that the soil-filled causeways had been used for dispersal to new locations (Engeman et al. 2006). Fortunately no Gambian giant pouched rats were found on keys connected to Crawl Key by earth-filled causeways, nor on Long or Knights Keys with transfer sites for refuse or hurricane debris.

On Grassy and Crawl Keys, Gambian giant pouched rats were observed only in drier rockland hammock habitat (Florida Natural Areas Inventory 1990). Gambian giant pouched rats were found in a 2-km band of this habitat on Grassy Key extending east and west from the site where the escape originated. However, they were not observed in similar, apparently suitable habitats towards the eastern end of Grassy Key. The preferred habitat for Gambian giant pouched rats coincided with the habitat most suitable for human development. While Gambian giant pouched rats were found in undeveloped rockland hammock habitat, human development of this habitat greatly enhanced these areas for Gambian giant pouched rat occupation through provision of a greater bounty of resources, such as refuse, pet food, fresh water, and refugia. They did not appear to inhabit wet shrub and

mangrove habitats. A small radio-telemetry data set also confirmed the observations by the various detection methods concerning habitat preferences. Moreover, radio-telemetry demonstrated Gambian giant pouched rats, males in particular, are capable of overnight movements of nearly 1 km (Engeman et al. 2006). However, information from their native African range suggests that the Gambian giant pouched rats do not move very far; usually only repeated movements between a food source and their burrow (Smithers 1983).

Bait and Toxicant Development

Live-trapped Gambian giant pouched rats were used to rapidly evaluate bait acceptance and efficacy. The toxicants tested included 2.0% zinc phosphide (ZP), an acute toxicant, in a peanut butter and horse sweet mix matrix (corn, oats, molasses) and four commercial anticoagulant baits: Ramik® mini-bars (0.005% diphacinone, first generation anticoagulant), Contrac® (0.005% bromadiolone, second generation anticoagulant), Havoc® (0.005% brodifacoum, second generation anticoagulant), and d-Con® (0.0025% difethialone, second generation anticoagulant). Among the commercial anticoagulant baits, the Gambian giant pouched rats showed the greatest acceptance for the Ramik® mini-bars over the three second generation anticoagulants baits. All rats consumed this bait and died in 5-11 days. All rats presented with the ZP bait died in $\leq$43 h (most in < 24 h), after consuming a small amount (mean = 7.3 g) of the ZP bait (Engeman et al. 2006).

Based on those results, two rodenticide baits appeared most valuable for use on Gambian giant pouched rats: the first generation anticoagulant, 0.005% diphacinone (Ramik mini-bars), and the acute 2% ZP bait (mixed with peanut butter and horse sweet mix). The Ramik bait would need to be presented continuously for at least a two-week period to assure consumption of a lethal dose, whereas, a small amount of the acute ZP bait consumed in a single feeding would be lethal.

A commercial bait station (Protecta®, Bell Laboratories Inc., Madison, Wisconsin) and a custom-designed bait station made of PVC pipe (Engeman et al. 2006) were tested using untreated bait to determine bait accessibility for Gambian giant pouched rats, and exclusion of native species. Over 600 photographic observations of the PVC pipe bait station demonstrated delivery of bait to Gambian giant pouched rats while minimizing exposure to native species. The commercial bait station appeared to exclude native mammalian species, but also restricted adult Gambian giant pouched rats from access (Engeman et al. 2006).

Influence of Non-Target Species

Sympatric populations of non-target species, especially raccoons, existed in great abundance, presenting a threat to improperly configured control and monitoring devices intended for Gambian giant pouched rats. Control devices must exclude non-target species, and monitoring devices needed to accommodate many non-target visits and still be able to detect Gambian giant pouched rats.

The camera methodology used to detect Gambian giant pouched rats was not hindered by large numbers of non-target animals. On the other hand, based on camera observations, non-target species could potentially remove all bait from bait stations (and probably die) before Gambian giant pouched rats would have a chance at the bait. However, this problem was averted by the innovative bait station design. The same could not be said for trapping. Trapping would still be required in areas where bait was not permitted by property owners, where rats consumed a sublethal dose and became aversively conditioned to the bait, or for rats not attracted to the bait stations to begin with. In these situations, non-target animals could pose significant obstacles to Gambian giant pouched rat removal through trapping.

PILOT ERADICATION ON CRAWL KEY

Prior to implementing full-scale eradication on Grassy Key, a pilot eradication project was implemented to test and fine-tune the methods on Crawl Key adjoining Grassy Key where the species expanded its range. In addition to the governmental entities involved in the project, partial funding also was provided by the Wildlife Foundation of Florida, Inc. The information accumulated on Gambian giant pouched rats and control methods was formulated into an eradication plan and tested on this small Key.

Because the ZP bait was readily accepted with only minimal consumption required for a lethal dose (thereby increasing the likelihood a lethal dose would be consumed at the bait station with a single visit), it was selected as the bait of choice. A 40 x 40 m grid of bait stations was established for Crawl Key, and was based on the radio-telemetry data, information from the literature, and personal experience (GW) in eradication of other rat species from other islands. Pre-baiting using the same bait matrix without the toxicant is common and often

recommended on the labels for ZP baits to help prevent “bait-shyness” whereby animals become somewhat sick from a sublethal dose, and decline to eat that bait again (for a review, see Salmon et al. 2000). Therefore, pre-baiting in the PVC bait stations was done for three days using the bait matrix without the toxicant. Following that, any remaining bait matrix was removed and toxic bait (2% ZP) was applied for seven days. All of Crawl Key was baited at the same time (97 bait stations).

Preliminary camera surveys following the completion of the pilot eradication found no evidence of Gambian giant pouched rats remaining on Crawl Key. However, the highly destructive Hurricane Wilma struck in the intervening time. Its storm surge over washed much of the island with up to 1 m of water, which may have also contributed to their mortality. Further monitoring of Crawl Key is required, however, to assure the successful eradication from that island.

ERADICATION ON GRASSY KEY

Planning the Eradication

The criteria for a successful eradication (see Parkes and Murphy 2003, Engeman et al. 2006) were considered obtainable and an eradication effort subsequently was commenced on larger Grassy Key, the location of the primary Gambian giant pouched rat population. Surveys on Grassy Key following Hurricane Wilma verified the survival of the Gambian giant pouched rat population with, possibly, a greater occupied area. That the rats survived the hurricane on Grassy Key provided sound evidence that they probably could have survived also on Crawl Key, and their absence there was most likely due to bait consumption or because a longer period of monitoring is required.

In late 2006 and early 2007, the population surveys on Grassy Key were completed and used to design bait station density and distribution across the island. Not all of Grassy Key appeared to hold Gambian giant pouched rats, especially areas with inferior (very wet) habitat. Nevertheless, baiting was conducted throughout the entirety of the island where high water was not an issue. However, bait station density was varied between two levels according to the probability that Gambian giant pouched rats were present in the vicinity. The areas known to support Gambian giant pouched rats had a bait station placement design on a 40 x 40 m grid, whereas the perceived marginal areas for Gambian giant pouched rats had a 50 x 50 m grid. A public meeting, mailings, and door-to-door visits were conducted to get public approval among the 494 property owners. A toll-free hotline was established to provide information on eradication time lines and progress. Still, some property owners either would not grant permission to enter their property or would not allow toxic bait on their property. Baiting was planned to be conducted as close to those properties as legally permissible. Even so, trapping was thus anticipated to be a necessary addition for eradication.

Implementing the Eradication

To avoid hazards to, and interference from non-target species during baiting, live-trapping was conducted to safely remove non-target animals to a nearby island. The South Florida Water Management District funded private contractors to cut the necessary trails for establishing the bait station grids. Next, 1,000 bait stations were installed at the predetermined spacings, a process that extended from January through May due to personnel constraints and competing priorities. Because of the large number of bait stations, all bait stations on the entire island could not be serviced simultaneously. Baiting with the 2% ZP formulation was conducted in May-June 2007 in a "rolling front" strategy. The island was divided longitudinally into zones. Bait was applied to one zone at a time, moving from east to west. Pre-baiting was again applied for three days using the nontoxic bait matrix, followed again by seven days of baiting with toxic bait.

Current Status

In areas holding Gambian giant pouched rats, it appeared that high percentages of non-toxic bait were commonly removed from bait stations during pre-baiting, but much lower quantities of toxic bait were removed, probably indicating single feeding mortality or a relatively low acceptance rate. It became quickly clear that some Gambian giant pouched rats remained after the baiting effort. Camera surveys following completion of baiting revealed at least four hotspots of Gambian giant pouched rat activity. These sites have been primarily associated with residential areas where numerous alternative food sources, such as pet food, are available. A few activity sites also have been associated with properties where the owners did not permit the use of toxicants. These final hotspots are being addressed with intensive trapping using cantaloupe as a food bait in the cage traps. The surrounding bait stations are also being re-baited with the ZP bait, mixing the ZP with

horse sweet mix and cantaloupe oil. This approach will hopefully be successful, especially as the translocation of raccoons and opossums away from Grassy Key has reduced non-target animal interference with traps to much lower levels. One hotspot, where the property owner did not allow toxicants and also had fresh water and pet food available, has been repeatedly trapped, but Gambian giant pouched rats remain in the area. Because eradication is proving very difficult under the conditions on Grassy Key, alternative rodenticides are being investigated. However, preliminary trials with Ramik mini-bars and Ramik Green pellets (diphacinone) and captive rats being fed a diverse diet has shown this rodenticide bait to be inadequately palatable to the Gambian giant pouched rats. A brodifacoum pelleted bait (Brodifacoum 25–Conservation) is also being investigated, and preliminary results are promising. If an effective, alternative bait is found, the entire island will be baited using the bait station grid once approval is obtained from the Florida Department of Agriculture.

DISCUSSION

Gambian giant pouched rats will be considered eradicated when intensive surveys do not reveal the presence of rats for two years, with the caveat that vigilance and periodic surveys will continue past that time to ensure no remnants of the population have gone undetected and survived to breed. The areas of any detected rats would be targeted with intensive control efforts. If this invasive species can be successfully eradicated from the Florida Keys, hopefully, this would help reduce the general reluctance of managers to attempt eradications of other invasive species in Florida (see, for example the comments by Donlan et al. 2003).

Teamwork, Resources, and the Future

The logic and flow described here for this eradication effort may make it seem as though the path to Gambian giant pouched rat eradication was a smooth continuum once the problem was identified. In reality, it was a series of fits and starts, beginning in August 2004 and continuing to date. There was no sizable and continuous block of funding available to develop the necessary information and implement an eradication effort. Funding and in-kind resources were provided from several federal, state, and local government entities, as well as private concerns. Work towards eradication has been conducted to the fluctuating level of the resources available.

Work will continue towards the eradication of Gambian giant pouched rats on Grassy Key as long as resources are available. Once the eradication effort appears to have been successful, however, that does not imply the eradication effort would be complete. At least two years of monitoring for Gambian giant pouched rats should be applied to both Grassy and Crawl Keys. Moreover, similar monitoring efforts should be applied to transfer sites for refuse from Grassy Key, including the mainland landfill(s). While investigation of unconfirmed, but credible reports of sightings on other keys did not locate any Gambian giant pouched rats, these areas should also receive continued monitoring to help insure no individuals from Grassy Key are surviving elsewhere in the Florida Keys. This ongoing monitoring effort will require funding, as would a rapid response to any confirmed locations of Gambian giant pouched rats. Hopefully, complacency with the accomplishments so far would not undermine availability of necessary resources to continue mop-up work of remaining rats and to do the follow-up monitoring portion of the effort to its conclusion. Lack of continued vigilance could result in the hard work and expended resources to date being undone, or worse, eventual Gambian giant pouched rat dispersal to the mainland.

Although obtaining adequate resources to maintain steady work towards eradication is challenging, the effort will, hopefully, be successful in the end. If successful, the approach developed here could serve as a model for preparing control or eradication efforts for other potentially destructive invasive species. This is especially true in Florida, which often serves as the gateway to North America for non-native introductions (US Congress 1993). Similar to the case of the Gambian giant pouched rat, the rapid development of detection, monitoring, and control methods could quickly lead to implementation of successful control or eradication procedures while a practical opportunity exists to contain and/or remove their populations.

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