August 2000

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Abstract: The accidental introduction of the brown treesnake (*Boiga irregularis*) to Guam led to the demise of most of the island's native avifauna and herpetofauna. The snake is also responsible for significant economic losses through frequent power outages and consumption of poultry. Control of the snake, aimed at preventing its inadvertent dispersal from the island and protecting native wildlife and economic resources, is accomplished using specially designed snake traps, hand capture, snake detector dogs, and snake barriers. Although control tools capture large numbers of snakes, control efforts are labor intensive, costly, and ineffective in reducing snake populations across the unbroken forested landscapes found throughout much of the island. The efficacy of control methods has been widely researched; however, no comprehensive evaluation of the cost-effectiveness or ideal integration of control tools in differing scenarios has been completed. In this paper, we present an overview of current federal control efforts and discuss the costs and limitations of snake control.

Key words: *Boiga irregularis*, brown treesnake, canine inspections, Guam, invasive species, trapping, wildlife damage management

The brown treesnake (BTS), *Boiga irregularis*, accidentally brought to Guam after World War II, is an extreme example of the impacts an introduced predator can have on native insular fauna (Savidge 1987). Currently, 3 of 12 species of native forest birds survive in the wild, with 1 of those on the verge of extinction (Savidge 1987, Wiles et al. 1995). The Guam population of Mariana fruit bats (*Pteropus mariannus*), already threatened by over-hunting, has been suppressed by snake predation (Wiles et al. 1995). In addition, snake predation threatens many of Guam's 11 native lizards (Rodda et al. 1992).

Guam has also suffered economic and social consequences from BTS introduction. Snakes have become agricultural pests through depredations on poultry and other small domesticated animals (Fritts and McCoid 1991). Snakes climbing on utility poles and wires cause frequent power failures that result in millions of dollars of damaged equipment, lost productivity, and repair costs (Fritts et al. 1987). Furthermore, the mildly venomous snake frequently enters homes, where it endangers small children (Fritts et al. 1990).

Brown treesnakes are opportunistic feeders that consume a highly varied diet (Savidge 1988, Linnell et al. 1997, Rodda et al. 1997), and they can survive in close proximity to human development. The snakes are agile climbers that seek refuge from heat and light during daylight, occasionally in cargo, shipping containers and transport vessels. These characteristics, coupled with Guam's position as a focal point for commercial and military shipments of cargo and passengers throughout the western Pacific and Hawaii, present a significant threat of snake dispersal. Brown treesnakes originating from Guam have been documented on many Pacific islands, and as far away as Texas and Spain (McCoid et al. 1994, Fritts et al. 1999). An incipient population is suspected on Saipan in the Commonwealth of the Northern Mariana Islands (McCoid et al. 1994, Fritts et al. 1999). The establishment of snake populations in other locations could result in ecological and economic consequences similar to those observed on Guam, in addition to serving as source populations for future dispersal (Fritts et al. 1999, Kaiser et al. 2000).

CONTROL OVERVIEW

Control of the BTS on Guam has been ongoing since the early 1990s. As federal and local control efforts have expanded, the development of effective snake traps, barriers, and detector dogs has increased control efficacy. However, control tools effective over large areas, although researched, have not been developed. As a result, control efforts on Guam are not focused on island-wide eradication, but rather, area-specific population reductions.

Control Objectives

Brown treesnake control on Guam focuses on 3 primary goals: (1) prevention of dispersal from the island, (2) protection of native wildlife, and (3) protection of economic resources. A limited number of control tools are available in support of these objectives and are summarized in the following sections.

Trapping

Trapping, the primary method of snake removal, is conducted at numerous locations throughout Guam. Several trap designs are in use and all are variations of modified minnow or crawfish traps. The trap design considered in this paper is the standard operational trap used by the U.S. Department of Agriculture's Wildlife Services (WS) Program (Linnell et al. 1998, Vice et al. unpublished data). Trapping strategy is determined by the objective of the control efforts (Engeman and Linnell 1998). Traps are hung either on vegetation or chain-link fencing. When hung in vegetation, traps are placed primarily along the perimeter of forest fragments that are typical of habitat surrounding ports of exit. Traps placed in such a perimeter configuration have been found to be effective in removing snakes from discrete blocks of forest of up to 20 ha in size (Anderson et al. 1998, Engeman and Linnell 1998, Engeman et al. 1998b, Engeman et al. 2000). Traps placed in a grid pattern (interior placement) may be used in support of native wildlife recovery efforts, particularly in locations with large expanses of unbroken forest, or to validate the effectiveness of perimeter trapping.

Most ports of exit on Guam are surrounded by perimeter fences, which provide an effective and efficient trap hanging substrate (Engeman and Vice 2000, Engeman and Vice 2001). Such traps target snakes that have entered the perimeter of cargo staging areas and are at high risk of accidental shipment off Guam (Engeman and Vice 2001). In addition to improving operating efficiency, perimeter fences provide security from trap theft and vandalism.

While trapping is an effective means for capturing snakes, trapping efficacy is limited by the accessibility of the targeted control area and the potential size biases in snake capture distribution (Engeman and Linnell 1998, Rodda et al. 1999). In addition, there are significant logistic constraints to the use of traps. The use of traps is cost and labor intensive and the positive results achieved through trapping are quickly lost if trapping ceases. Each trap houses a live laboratory mouse that serves as a lure. Care and maintenance of the live mouse requires exceptional resource dedication. In addition to providing food and water (whole potatoes provide water) to the mouse on a weekly basis, control personnel must fabricate the blocks of feed used in the traps, regularly clean and maintain traps to ensure operational utility, and care for colonies of mice which supply the lures for the traps.

The initial installation of a single trap is estimated to cost US$65; approximately US$55 are the costs associated with trap fabrication and shipping (USDA Wildlife Services unpublished data). Other costs include the lure mouse, trap cover, feed block, and potato. A single technician can operate and maintain approximately 300 snake traps. The manageable number of traps decreases as traps are placed in forest interior configurations or as the distance between control sites increases.

Spotlighting

The climbing habits of BTS facilitate efficient hand capture in some circumstances (Rodda 1991, Engeman and Vice 2001). Introduced geckos, an important food source for BTS, are abundant on fences and may attract foraging snakes. Because most ports of exit are surrounded by a perimeter chain-link fence, spotlighting perimeter fences becomes an effective means for capturing snakes. Spotlighting involves either driving or walking perimeter fences surrounding control sites and illuminating the fence with a high-powered spotlight. Snakes encountered on the fence are subsequently removed by hand. Spotlighting is an efficient method used to supplement trapping efforts. Spotlighting captures account for 30% or more of the monthly snake take in some control areas and may remove different size distributions of snakes than traps (Engeman and Vice 2001, USDA Wildlife Services unpublished data).

Canine Inspections

While trapping and hand capture may remove the majority of snakes in and around cargo facilities, some snakes are able to circumvent existing control efforts. To detect snakes that may have avoided other control measures, outbound cargo and cargo vessels are subjected to inspection by dogs (Jack Russell terriers) trained to detect BTS. Inspections are conducted at all commercial and military ports of exit on Guam. Cooperative in nature, the WS program on Guam has established snake control agreements with most private and public cargo handlers (Vice et al. 2001). The positive relations between WS and cargo shippers has provided an opportunity to summarize outbound cargo flow from Guam and subsequently prioritize the application of detector dog inspections (Vice et al. 2001). A large proportion of cargo leaving Guam is vulnerable to snake incursion. Cargo arriving in locations susceptible to snake colonization (e.g., most Pacific Basin islands and Hawaii) is considered high risk, even if inspected prior to departure. Vice and Engeman (2000) describe canine inspection sites on Guam.

The efficacy of canine inspections is difficult to assess. True rates of detection would require knowledge of all cargo incursions by BTS and the recovery of missed snakes in cargo- receiving locations (Engeman et al. 1998b). Because such information is impossible to obtain, blind field trials using snakes hidden in cargo, were used to establish baseline canine detection rates. Snake detection rates varied between 35% and 70%, depending upon the relative frequency of evaluations and whether an evaluator was present (Engeman et al. 1998b).

Successfully training a single canine handler requires a significant time and resource commitment. A typical handler trainee will complete the basic training program in 5-7 months. Follow-up training and evaluation must occur at regular intervals (several times per year) to maintain handler proficiency. The intensive training required of newly hired handlers dictates some failure among handlers. However, typical “wash-out” rates for the WS program have been lower than other federal detector dog programs. When determining the fate of a new handler, the costs of personnel replacement must be balanced with the potential impacts of compromised-quality inspections.

Snake Barriers

Physical barriers to snakes have been developed for use in both cargo protection and wildlife protection scenarios. A variety of barriers have been designed and tested in controlled settings (Perry et al. 1998). Operational use of barriers has been relatively limited in scope and not well-evaluated.

WS has installed and used a temporary barrier constructed of Solartex "Weathershade" (a fabric used in greenhouses), PVC pipe, and rebar (Perry et al. 1998) in support of snake containment efforts during large scale military exercises. The barrier delineates a "snake sterile" zone, where outbound cargo is staged and processed prior to departure. In addition to providing protection from potential snake invasion, the temporary barrier acts as a cargo (choke point,(that facilitates thorough canine inspections of outbound cargo.

A wire-mesh, semi-permanent barrier, fitted to an existing chain-link fence, is currently in use in support of native wildlife recovery efforts in a 22-ha forest block on the northern end of the island (Anderson et al. 1998), where endemic Guam rails (*Gallirallus owstoni*) have successfully bred outside of captivity for the first time since the 1980s. Permanent barriers, constructed of concrete, and/or vinyl seawall material, have been proposed at a number of cargo staging and wildlife recovery sites throughout Guam. These barriers would serve as additional snake protection for native wildlife as well as staged cargo and vessels prior to departure from Guam. As part of the developing plans for further recovery of Guam's native wildlife, a concrete barrier surrounding the 580-ha Munitions Storage Area on Andersen Air Force Base has been proposed.

Prey-Base Control

Prey-base control involves population reduction of introduced birds and mammals, such as rats (*Rattus* spp.), rock doves (*Columba livia*), Eurasian tree sparrows (*Passer montanus*), and black drongos (*Dicrurus macrocercus*), in and around cargo facilities. The goal of prey-base control is to reduce the attractiveness of an area to snakes and subsequently reduce the likelihood of snakes entering cargo facilities in search of food. The primary methods of control for avian species are shooting and live traps. Rats are controlled using anticoagulant baits registered with the U.S. Environmental Protection Agency.

PROGRAM COSTS

The budget for WS BTS control activities on Guam was approximately US$1.7 million for fiscal year 2000 (FY00). During FY00, US$300,000 was allocated for the design and installation of a permanent snake barrier at the international airport. WS operations on Guam are supported by an administering office in Honolulu, HI, with an annual budget of US$300,000. Additionally, the U. S. Department of Defense provides approximately US$400,000 annually for "hidden costs," including kennel space and veterinary care for detector dogs, and office and shop space for 25 employees.

The Guam WS program currently employees 3 wildlife biologists, 2 canine trainers, 2 administrative assistants, 13 canine handlers, and 16 wildlife specialists. In addition, 3 full-time technicians construct traps in a shop facility in Yakima, WA. Operations are conducted out of 3 field offices and kennel space is located on 2 military installations. The program uses 14 detector dogs and operates a fleet of 30 federally owned vehicles. The scope of work provides coverage throughout the island(s transportation network and results in the removal of 3,500-5,000 BTS annually. Removal numbers reflect high costs per snake. Because WS efforts focus specifically on protection of cargo resources, control is applied in close proximity to cargo handling facilities. Annual snake removal could be significantly higher if WS efforts were expanded outward from such port locations. Funding limitations, security issues, and other constraints do not currently allow for such expansion.

LIMITATIONS WITH CURRENT CONTROL EFFORTS

A primary concern regarding BTS control is the intensiveness, both of cost and labor, necessary to remove snakes. In addition, the long-term viability of control is dependent, for the foreseeable future, upon perpetual control. Current control focuses on the creation of snake-reduced "islands" within a larger snake-rich landscape. Snake re-invasion occurs quickly if control efforts cease (Savarie et al. 2001). Funding for BTS control work has been annually appropriated, and as such, concerns over the long-term viability of (soft money(reduces the ability of individual programs, particularly research, to develop long-term infrastructure. The lack of secure year-to-year funding may indirectly limit control efficacy.

The suite of available tools selectively control segments of the BTS population on Guam. Although traps effectively capture snakes, extremely small, large, and gravid snakes tend to be undersampled by trapping. This capture bias may result in a significant proportion of snakes remaining in a given control area despite very few or zero trap captures. The use of hand capture to supplement trapping efforts may partially alleviate size-bias issues, but hand capture is only logistically feasible in locations surrounded by chain-link fencing (Rodda 1991, Engeman et al. 1999, Engeman and Vice 2001). The selectivity of traps may also be manifested through trap shyness, independent of size biases. Given the potential selectivity of control, an integration of techniques, including the use of barriers to prevent re-invasion of snakes, is appropriate in most control situations.

Brown treesnakes are relatively easy to capture in areas with high snake densities. Despite the incipient population suspected on Saipan, intensive trapping and nighttime spotlight surveys during the past several years have yielded no snakes using either method. Superabundant prey and the relatively sparse distribution of an incipient population may reduce the probability of snake detection using either method. As such, the detection and control of BTS at low, but increasing, densities does not currently appear possible. Research to determine means of detecting, and subsequently eradicating, incipient BTS populations has been identified as a critical component of future research.

FUTURE DIRECTIONS

The development of an inanimate BTS lure to replace the live lab mouse used in trapping, would greatly improve the efficiency of snake trapping. The use of live mice for trapping requires (at a minimum) weekly visits to each trap to provide food and water for the lure. Traps are of limited use in remote areas and are more difficult to operate and maintain when placed in the interior of forest blocks (Engeman et al. 1998a).

Research efforts are currently exploring possible long-term snake control options that may have applications over larger landscape areas than currently available control methods. The most promising future control technique appears to be the development of oral toxicants, particularly acetaminophen (Savarie et al. 2001). The use of a toxicant bait station, as described in Savarie et al. (2001), may significantly reduce the need for care and upkeep of the large number of mice currently supporting WS trapping efforts. In addition, toxicants may target a subset of snake populations not caught by traps or by hand, and therefore reduce residual snake populations in forested areas. Field evaluations of this developing method are currently underway, as are efforts to register the field use of oral toxicants. The addition of such control improvements provides hope for both the long-term viability of native wildlife recovery and for long-term reductions in the snake population throughout Guam.

Given the financial and logistic constraints of BTS control, the consequences of ceasing operations on Guam are significant. Estimates of the potential costs associated with BTS colonization of Hawaii are US$300 million per year (Kaiser et al. 2000). For this reason, the seemingly expensive efforts to prevent snake dispersal from Guam provide significant economic and ecological savings over possible future costs associated with detection and eradication of incipient snake populations that would likely develop if no control was applied in Guam (Kaiser et al. 2000, Pimentel et al. 2000).

LITERATURE CITED

Anderson, R. D., G. M. Beauprez, and A. D. Searle. 1998. Creation of a snake-free area on Guam using trapping and barrier technology. Brown Treesnake Research Symposium. Honolulu, Hawaii, USA.

Engeman, R. M., and M. A. Linnell. 1998. Trapping strategies for deterring the spread of brown treesnakes from Guam. Pacific Conservation Biology 4:348-353.

Engeman, R. M., M. A. Linnell, P. Aguon, A. Manibusan, S. Sayama, and A. Techaira. 1999. Implications of brown tree snake captures from fences. Wildlife Research 26:111-116.

Engeman, R. M., S. Sayama, and M. A. Linnell. 1998a. Operational utility of perimeter trapping for removing brown tree snakes (*Boiga irregularis*) from a defined area. The Snake 28:19-22.

Engeman, R. M., and D. S. Vice. 2000. Standardizing the evaluation of brown tree snake trap designs. Integrated Pest Management Reviews 5:205-212.

Engeman, R. M., and D. S. Vice. 2001. A direct comparison of trapping and spotlight searches for capturing brown tree snakes on Guam. Pacific Conservation Biology 7:4-8.

Engeman, R. M., D. S. Vice, G. Nelson, and E. Muña. 2000. Brown tree snakes effectively removed from a large plot of land on Guam by perimeter trapping. International Biodeterioration and Biodegradation 45:139-142.

Engeman, R. M., D. S. Vice, D. V. Rodriguez, K. S. Gruver, W. S. Santos, and M. E. Pitzler. 1998b. Effectiveness of the detector dogs used for deterring the dispersal of brown tree snakes. Pacific Conservation Biology 4:256-60.

Fritts, T. H., and M. J. McCoid. 1991. Predation by the brown tree snake (*Boiga irregularis*) on poultry and other domesticated animals on Guam. The Snake 23:75-80.

Fritts, T. H., M. J. McCoid, and D. M. Gomez. 1999. Dispersal of snakes to extralimital islands: incidents of the brown treesnake, *Boiga irregularis*, dispersing to islands in ships and aircraft. Pages 209-223 in G. H. Rodda, Y. Sawai, D. Chizar, and H. Tanaka, editors. Problem snake management: the habu and the brown treesnake. Cornell University Press, Ithaca, New York, USA.

Fritts, T. H., M. J. McCoid, and R. L. Haddock. 1990. Risks to infants on Guam from bites of the brown tree snake (*Boiga irregularis*). American Journal of Tropical Medicine and Hygiene 42:607-611.

Fritts, T. H., N. J. Scott, jr., and J. A. Savidge. 1987. Activity of the arboreal brown tree snake (*Boiga irregularis*) on Guam determined by electrical outages. The Snake 19:51-58.

Linnell, M. A., R. M. Engeman, M. E. Pitzler, M. O. Watton, G. F. Whitehead, and R. C. Miller. 1998. An evaluation of two designs of stamped metal trap flaps for use in operational trapping of brown treesnakes (*Boiga irregularis*). Snake 28:14-18.

Linnell, M. A., D. V. Rodriguez, R. E. Mauldin, and R. M. Engeman. 1997. *Boiga irregularis*: incubation and diet. SSAR Herpetological Review 28:153.

McCoid, M. J., , T. H. Fritts, and E. W. Campbell, iii. 1994. A brown tree snake (Colubridae: *Boiga irregularis*) sighting in Texas. Texas Journal of Science 46:365-368.

Perry, G., E. W. Campbell, iii, G. H. Rodda, and T. H. Fritts. 1998. Managing island biotas: brown treesnake control using barrier technology. Vertebrate Pest Conference 18:138-143.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. Bioscience 50:53-65.

Rodda, G. H. 1991. Fence climbing by the arboreal brown tree snake, *Boiga irregularis.* Snake 23:101-103.

Rodda, G. H., T. H. Fritts, and D. Chiszar. 1997. The disappearance of Guam's wildlife. Bioscience 47:565-574.

Rodda, G. H., T. H. Fritts, C. S. Clark, S. W. Gotte, and D. Chizar. 1999. A state-of-the-art trap for the brown treesnake. Pages 268-305 *in* G. H. Rodda, Y. Sawai, D. Chizar, and H. Tanaka, editors. Problem snake management: the habu and the brown treesnake. Cornell University Press, Ithaca, New York, USA.

Rodda, G. H., T. H. Fritts, G. Perry, and E. W. Campbell. 1998. Managing island biotas: can indigenous species be protected from introduced predators such as the brown treesnake? Transactions of the North American Wildlife and Natural Resources Conference 63:95-108.

Roumasset, J., B. Kaiser, N. Krause, D. Mecham, and J. Wooley. 2000. Environmental valuation and the Hawaiian economy: introduction and executive summary. Draft report. University of Hawaii, Honolulu, USA.

Savarie, P. J., J. A. Shivik, G. C. White, J. C. Hurley, and L. Clark. 2001. Use of acetaminophen for large scale control of brown treesnakes. Journal of Wildlife Management 65:356-365.

Savidge, J. A. 1987. Extinction of an island forest avifauna by an introduced snake. Ecology 68:660-668.

Savidge, J. A. 1988. Food habits of *Boiga irregularis*, an introduced predator on Guam. Journal of Herpetology 22:275-282.

Vice, D. S., M. A. Linnell, and M. E. Pitzler. 2001. Draft summary of Guam's outbound cargo handling process: preventing the spread of the brown treesnake. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services. Barrigada, Guam.

Vice, D.S., and R.M. Engeman. 2000. Brown tree snake discoveries during detector dog inspections following Supertyphoon Paka. Micronesica 33:105-110.

Wiles, G. J., C. F. Aguon, G. W. Davis, and D. J. Grout. 1995. The status and distribution of endangered animals and plants in northern Guam. Micronesica 28:31-49.