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Substantial reductions of brown tree snake (*Boiga irregularis*) populations in blocks of land on Guam through operational trapping

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Abstract

Two plots of land on opposite sides of Apra harbor in Guam that had been operationally trapped to remove brown tree snakes were subjected to further trapping at greater intensity to assess the remaining populations of snakes. Trapping in both plots was only terminated after at least 4 weeks without a capture. Only 2 snakes were captured in a 4.2 ha plot and 4 were captured in a 6.5 ha plot. Tagged snakes were released into an adjacent plot that was across a road from the 6.5 ha plot and had a bordering trap line as a barrier to deter snakes from exiting it into other plots or wharf areas. None of these snakes was found to have passed through the barrier trap line and crossed the road. Operational trapping methods were concluded to be highly effective in this developed area where optimal forested snake habitat occurs in a patchy distribution. Published by Elsevier Science Ltd.

1. Introduction

The brown tree snake, *Boiga irregularis*, is an exotic species that was inadvertently introduced to the island of Guam, probably in the 1940s (Fritts, 1987, Fritts, 1988; Rodda et al., 1992). Since then, it has been responsible for the extirpation or substantial reductions of many species of indigenous birds (Savidge, 1987), native lizard populations (Rodda and Fritts, 1992a), and fruit bats (Wiles, 1987a). It has also become a significant problem for electrical utilities (Fritts et al., 1987) and a public health and safety risk (Fritts et al., 1990). Guam's role as a shipping hub for air and sea cargo to many other parts of the Pacific and mainland United States has produced considerable concern about the potential for the further spread of the brown tree snake to other areas. In response, operational control and containment activities are carried out at Guam's air- and sea-port facilities to curtail the dispersal of the snakes. Much of the control effort has been directed at continual removal of brown tree snakes from these highest risk areas by a variety of trapping strategies.

Trapping has been shown to be effective for capturing brown tree snakes (e.g., Rodda and Fritts, 1992b, Engeman et al., 1998), however the resulting population levels have not been documented for operational trapping efforts. We used two blocks of land on the Guam Naval Station adjacent to Apra Harbor to evaluate the efficacy of operational trapping methods for removing brown tree snake populations and subsequently maintaining them at low levels.

2. Methods

2.1. General study area

Apra Harbor is the focal point for shipments of a large amount of military and commercial cargo. It is located on the west coast of the southern portion of the island of Guam and the naval reservation lands that surround most of the south and east portions of the harbor have been the focus for brown tree snake trapping. The land surrounding the harbor is heavily developed but is interspersed with blocks of land that are forested almost entirely with tangentangen trees (*Leucaena leucocephala*) and offer excellent brown tree snake habitat. The fragmented nature of forest habitat is characteristic of port areas and allows trapping to be applied on a parcel by parcel basis. The control strategy has been to trap a parcel until no snakes were captured for several months, at which time most of the traps would be removed. The traps that remained would be left on the perimeter of the

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plot as a maintenance measure (E. Muña, pers. comm.). Two plots of land on opposite sides of the harbor were selected for study. Trapping strategies for the initial control and the less intensive maintenance trapping differed somewhat between the two plots and are included in the plot descriptions.

2.2. Polaris point study plot

This plot was located on Polaris Point which juts into the north side of inner Apra Harbor. The study plot portion of this area was a 4.2 ha block (Fig. 1) of flat terrain covered with contiguous forest unbroken by roads, tracks, or structures. The land adjacent to the south side of the plot was forested and had never been trapped. It was separated from the study plot by a fence line and vehicle track. Operational trapping on Polaris Point originated in August 1994 when a maximum of 135 traps over a 6.3 ha area (21.4 traps/ha) were used in a control program that included our study plot. Trapping was conducted in the forest interior as well as around the perimeter of forested tracts. The area was considered essentially snake free in April 1995, after which it was maintained by an enclosing perimeter trap line to deter re-invasion and/or hinder any remaining snakes from exiting.

For evaluating the effects of operational trapping, the study plot was trapped at over twice the intensity, 51 traps/ha (214 traps/4.2 ha), as originally trapped during operational control to remove the snakes from the area. Traps were placed approximately 15 m apart around the perimeter of the plot. Trails were cut through the plot approximately 20 m apart, and traps were placed approximately 15 m apart along the trails. All traps were modified crawfish traps with one-way flaps installed (most flaps were wire mesh, although some were stamped metal or drilled plastic, Linnell et al., 1998), and a live mouse within an interior, protected chamber with necessary food and water resources served as an attractant. Traps were checked every 1-3 days and the number of captures recorded. Snakes captured on the perimeter line were recorded separately from those caught in the interior trap lines. Trapping was discontinued after no captures

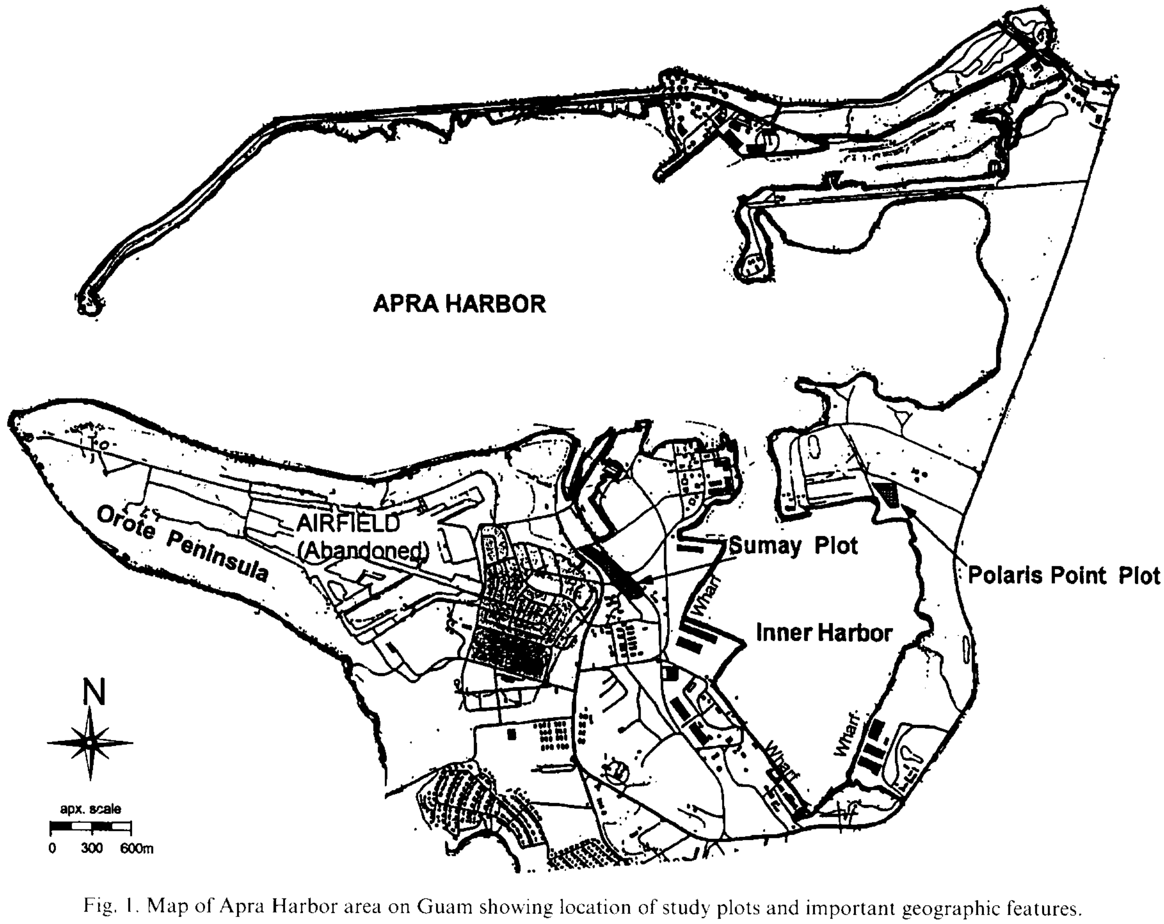

Fig. 1. Map of Apra Harbor area on Guam showing location of study plots and important geographic features.

were recorded for 4 weeks. Placement of traps was completed on 5 July 1995.

2.2. Sumay study plot

This 6.5 ha study plot was situated near the old Sumay village location on the south side of the harbor (Fig. 1) and represents a somewhat different operational approach and a different terrain than the Polaris Point site. Both Polaris Point and Sumay were originally trapped by utilizing trap placement within the forest interior, as well as around the perimeter of the forest. However, different strategies were applied as maintenance procedures after operational capture rates had dropped to zero and remained there. Sumay was initially trapped in July 1994 and by March 1995 it was considered essentially free of brown tree snakes and the bulk of the traps were removed. Barrier trap lines were maintained along one edge to deter any remaining or re-invading snakes from crossing the plot into the wharf area and also to hinder snakes from re-invading into the plot. Whereas the Polaris Point plot was encircled by a perimeter trap line, the Sumay plot was maintained by nearby barrier trap lines without completely encircling the plot. The vegetation at the 2 sites was virtually identical, but the topography differed between the plots. Unlike Polaris Point which is flat, the Sumay plot contained a small cliff line that could provide additional refuge for snakes. Trap placement for the Sumay segment of this study was completed on 19 July 1995. Here too, the trap intensity was approximately twice the trap intensity (260 traps, 40 traps/ha) as was originally conducted (130 traps, 20 traps/ha) at this plot. As with the Polaris Point study plot, traps were checked and the number of captures recorded every 1–3 days, with snakes captured on the perimeter line recorded separately from those caught in the interior trap lines. Trapping was discontinued after no captures had been recorded for 4 weeks.

In addition to assessing the trapable population of snakes in this plot, data on snake movements relative to trap lines and roads were also acquired. Twenty Microchip Identification Tag (MIT) marked snakes were released into the untrapped area opposite the barrier trap line from the Sumay plot on 20 July 1995. The interior of this area had not been operationally trapped, because it was listed as chemically contaminated. On the edge of this plot opposite Sumay, a trap line was maintained to deter brown tree snakes from invading the Sumay plot from this area. A paved road also lay between the contaminated area and the Sumay plot. Thus to invade the Sumay plot from the contaminated area, a snake would have to pass through a trap line, move to the ground and cross a road. This clearly would not be remarkable for these snakes, but the MIT marked snakes could yield information as to how likely or how quickly such invasion might take place.

3. Results

3.1. Polaris point study plot

Despite the saturation of the study area with traps, only 2 snakes were caught, both in perimeter traps. Both captures were made by 3 July 1995, prior to completion of trap placement. No further captures were made after this date, and on 4 August all of the traps were removed from this plot after 32 days had elapsed without a capture.

3.2. Sumay study plot

Capture results for this larger plot were similar to those at the Polaris Point plot. Only 4 snakes were captured, with the final capture on 9 August 1995. As with Polaris Point, all were captured in perimeter traps. The 4 weeks without capture stopping criterion was met, and trapping for the purposes of this study was discontinued on 7 September 1995 after 29 days without a capture.

Six of the 20 MIT-marked snakes were recaptured at 4, 12, 19, 19, 25, and 39 days after release. All were taken in the barrier trap line adjacent to the contaminated area across the road from the Sumay plot. This barrier trap line was temporarily removed on 1 September 1995 while safety concerns for trapping adjacent to a contaminated area were addressed. While the traps were later reinstalled shortly after the conclusion of our study, the disruption thereby eliminated 6 days of potential capture information from the barrier trap line. Given this event and that the snakes released into the contaminated area could travel in directions other than towards the trap line, and that these snakes are highly mobile (Santana-Bendix et al., n.d.; Wiles 1986, 1987, 1988), a 30% recapture rate was notable.

4. Discussion

There have been few situations where concerted efforts have been made to remove populations of snakes. Little success has been obtained in eliminating the habu (*Trimeresurus flavoviridis*) from relatively small areas on Japanese islands (Hayashi et al., 1983, Tanaka et al., 1987). In contrast to the habu, the arboreal brown tree snake has been demonstrated to be susceptible to trapping (e.g., Rodda and Fritts, 1992b, Engeman et al., 1996). Previous studies have indicated that Orote Peninsula (Fig. 1) has held snake densities of 58 snakes/ha (Rodda et al., 1992), with 1995 population estimates ranging from 11 to 20 snakes/ha (G. Rodda, pers. comm.). As the Sumay plot was located at the base of the Orote Peninsula, the paucity of snakes captured in this study is evidence that brown tree snakes can be virtually eliminated from a plot and maintained at very low numbers.

Given the intensity of trapping in this study and the propensity for brown tree snakes to be captured by such trapping methods (Rodda and Fritts, 1992b, Engeman et al., 1996), indications are that only very low brown tree snake populations remained following operational trapping in the plots around Apra Harbor. We can make a speculative effort to calculate the probability that snakes remained in our study plots after our trapping effort. There can be little doubt that the snakes in the two plots would have been exposed to the traps, as the available information on brown tree snake movement (Santana-Bendix et al., n.d.; Wiles, 1986, 1987b, Wiles, 1988) indicates that they are highly mobile snakes. Various studies conducted by the National Biological Service (NBS) to date have indicated a general range of 0.06 to 0.16 as daily population capture probabilities (G. Rodda, pers. comm.). Realizing that these capture probabilities are specific to the trapping layout from which they were estimated, we can make some additional assumptions and use these figures as starting points to calculate probabilities of snakes remaining in the plots. By assuming that daily population capture probabilities represent the daily capture probabilities for individual snakes and that these probabilities are representative for snakes on the Polaris Point and Sumay study plots during the time of this study and that escape rates from this study were essentially the same as in the NBS studies, we can use the binomial probability distribution to calculate a range of probabilities for whether snakes remained in our study plots while trapping proceeded for 30 days without a capture.

If we assume the lower-end capture probability presented by the 0.06 estimate, then there is a 0.16 probability that snakes would be in the plot, but no snake would be captured for 30 days. However, if the higher daily capture probability figure of 0.16 is more reflective of the true situation, then there would only be a 0.005 probability of no captures for 30 days. Because of the very intense trapping conducted for this study, one would expect the daily capture probabilities to be towards the high end or higher, thus implying the probability that snakes remained is lower. What we can conclude from this exercise is that the trapping conducted as part of this study probably removed the catchable snakes in the study plots. These very low capture numbers are indications that the original operational trapping combined with the maintenance trapping procedures were effective in keeping brown tree snake populations at negligible levels. In addition, because all snakes were captured in perimeter traps, there is the possibility that the few snakes that were captured in this evaluation of the operational effects were not residents of the plots, but rather were potential invaders attempting to enter the plots from outside. Perhaps, perimeter trapping is a very effective strategy that takes advantage of snake movements along the forest edge (Engeman et al. 1998) and that also provides a formidable hazard to snakes entering from outside.

Although numbers of marked snakes used were not extensive, it appears that the trap line along the contaminated plot across the road from our Sumay study plot posed a barrier to snakes potentially invading the Sumay plot. This barrier line was removed during the last week of our trapping in the Sumay plot, but no marked snakes crossed the road and were captured in the study plot. This does not constitute a meaningful test of a road as a barrier to invasion of a plot, but it is possible that roads or other open unforested areas are not as readily selected as routes of movement by brown tree snakes (Engeman et al., 1998).

We can now make some inferences about the effectiveness of operational trapping programs for removing brown tree snake populations from plots of fragmented habitat characteristic of port areas. Breaking of contiguous forest by roads, parking lots, lawns, buildings, and other developments obviously does not preclude the movement of brown tree snakes through the area, but it may deter them considerably. The operational trapping efforts that have taken place in this environment appear to have been highly effective at producing plots of land with very few brown tree snakes. This includes the initial trapping endeavor, which undoubtedly serves to eliminate most of the snakes present, as well as maintenance trapping using barrier or perimeter trap lines which serve as a drain on remaining and re-invading populations alike. The discontinuous habitat present around the harbor that is targeted for operational control is comprised primarily of relatively small blocks of forested habitat such as the 4.2 and 6.5 ha plots examined in this study. Engeman et al. (1998) indicated the efficacy of operational trapping using only a perimeter line in an 8.4 ha plot.

It might be possible to reduce brown tree snake numbers in larger areas on Guam by a strategic, sequential trapping program on the smaller plots that comprise the larger area. The information still needed to devise such a strategy includes determining the size of plot that can be effectively trapped until remaining snake populations are negligible and how long populations would remain reduced if no maintenance trapping were conducted.

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