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A direct comparison of trapping and spotlight searches for capturing Brown Tree Snakes on Guam

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Brown Tree Snake populations on Guam are controlled in the vicinities of cargo staging and transport areas to prevent their dispersal from Guam, and their populations are controlled in areas where endangered species are to be reintroduced. Trapping and night-time spotlight searches of fences are the two primary Brown Tree Snake population reduction methods used on Guam. We conducted a three month study comparing Brown Tree Snake captures by spotlighting fences to captures by trapping. Traps were placed either on the edge of the forest paralleling the fences, or they were hung on the fences. Applications of each capture method followed the standard practices used within the operational programme charged with deterring the spread of Brown Tree Snakes from Guam. We found captures by trapping to exceed those by spotlighting each month, but the captures by trapping decreased substantially over time, while those by spotlighting did not. We detected no differences statistically between numbers of captures taken by traps hung on the forest edge versus those hung on the fences. We found no differences in sizes of Brown Tree Snakes captured by spotlighting and trapping, based on average snout-vent length (SVL) or the distribution of SVLs. We feel that the two capture methods complement each other in an integrated pest management programme.

Key words: *Boiga irregularis*, Exotic species, Invasive species, Pacific islands, Snake control, Snake dispersal.

INTRODUCTION

THE Brown Tree Snake *Boiga irregularis* on Guam is a severe example of the negative effects that an introduced predator can have on native insular fauna (Savidge 1987). Its population irrupted after its accidental introduction following World War II and Brown Tree Snakes have caused the demise of most of the native avifauna and herptofauna (Savidge 1987), frequent power failures (Fritts *et al.* 1987), the loss of small domesticated animals (Fritts and McCoid 1991), and a health threat to small children (Fritts *et al.* 1990). Brown Tree Snakes consume a highly varied diet and thrive in a variety of habitats on Guam, including in immediate proximity to human development (Savidge 1988). These nocturnal snakes seek day-time refuge from heat and light, and sometimes take refuge in cargo, cargo containers, and transport vessels. These elements, coupled with Guam's importance as a trans-Pacific hub for commercial and military cargo and passengers, make further dispersal of Brown Tree Snakes from Guam a serious concern (Fritts *et al.* 1999; Vice *et al.* 1999).

A federal programme has been in place on Guam since late-1993 to deter the dispersal of Brown Tree Snakes (Engeman *et al.* 1998b; Vice *et al.* 1999). Of the methods applied in this integrated programme, two (trapping and spotlight searches of fences) are directed at controlling snake populations in the vicinities of air- and sea-ports, and other cargo staging areas. Trapping has been demonstrated as a means to rapidly reduce snake populations (Engeman and Linnell 1998) that, when applied over time, leaves very few snakes in the plot (Engeman *et al.* 1998a). Night-time spotlight searches of fences, is a labor-efficient method for capturing snakes, and it is widely applied because most areas targeted for Brown Tree Snake control also are interwoven with fences (Engeman *et al.* 1999). Moreover, in some areas trap damage caused by dogs, pigs or people makes trapping ineffective. In such instances, spotlight searches are the primary means of localized Brown Tree Snake population reduction.

Traps hung on the forest edge have been demonstrated to be a highly effective and efficient for capturing Brown Tree Snakes (Engeman *et al.* 1998c; Engeman and Linnell 1998), but traps hung on fences (in port cargo staging areas) have not been well-evaluated. Programmematic capture records have indicated a pattern of much higher initial capture rates over a wide area by trapping, followed by decreased captures over time (USDA/APHIS Wildlife Services unpublished data 1994–99), while captures through spotlighting fences remained relatively stable over time, ultimately becoming similar to captures by trapping.

A comparative understanding of the two methods, relative to the two trap placement strategies (fence or forest edge), should lead to optimal allocation of control resources and optimal integration of the methods to minimize populations of Brown Tree Snakes in areas targeted for population reduction. However, trapping and spotlight searches are disparate Brown Tree Snake control methods, which makes finding a comparative basis for application difficult. We felt that the most reasonable

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approach was to compare the methods as applied as standard operating procedures by the federal snake control programme on Guam. In that scenario, traps are checked on a weekly basis for snakes, and fences typically are searched by spotlight five nights per week.

METHODS

Four sites in and around the COMNAVMAR naval base in west-central Guam were used in this study. Each site had a similar length fence line (380–410 m) and previously had not been subjected to regular Brown Tree Snake control work. Each fence line ran parallel to a well-defined forest edge 3–7 m away. For each site, standard operational trapping and spotlighting procedures were applied. Our intention was to simultaneously target all snakes at each site by both trapping and spotlighting.

Half of the sites were randomly selected to have traps hung in trees along the forest edge at the operational control standard spacing of 20 m (Engeman and Linnell, in press), and checked weekly. The other half of the sites had traps hung on the fence, also with the operational standard 20 m spacing and weekly check. The traps were a funnel design (as in minnow or crayfish traps), customized for the capture of Brown Tree Snakes (e.g., Linnell *et al.* 1998), with one-way doors made of wire mesh installed at the entrances. A live mouse, protected in an interior cage, served as an attractant.

Snakes were captured on the fences through spotlighting five nights per week. Searches were conducted by illuminating fences with 3.1 million lumen spotlights from slowly moving (8–16 kph) vehicles once per night. The fences searched were 2.4 m chain-link fences with three parallel strands of barbed wire on 45° outriggers above the chain link portion. Captures continued at each site for three months, from November, 1998 through January, 1999. We did not consider spotlighting the forest edge as a comparative method, as it is not a practical in an operational control context (M. Pitzler, pers. comm.).

Snout-vent length (SVL) was measured and sex identified by hemipenis probe (Jordan and Rodda 1994) for captured snakes. Monthly capture data and SVLs followed repeated measures designs (Winer 1971) and were analysed as mixed linear models (e.g., McLean *et al.*. 1991; Wolfinger *et al.* 1991). In this model, trap placement (forest versus fence) was a fixed effect for which two sites each were chosen for study (random effect nested in trap placement). Capture method (trap versus spotlight), time (month) and gender were fixed (repeated) factors observed on each site. SAS PROC MIXED, with a restricted maximum likelihood estimation procedure (REML), was used to perform the calculations (Littell *et al.* 1996; SAS Institute 1992, 1996, 1997).

We conducted categorical data analyses using the size and sex data. Distribution of snakes between the genders was compared between the two capture methods using Pearson's chi-square test. We used size as an approximate guideline to delineate juvenile and adult snakes; snakes under 950 mm SVL were classified as juveniles, and snakes larger than 950 mm SVL were classified as adults (Rodda *et al.* 1999c; E. Campbell III, pers. comm.). The distribution of snakes between age classes also was compared for the two capture methods using Pearson's chi-square test. We also examined the distribution of Brown Tree Snakes among four size classes (≤749 mm, 750–999 mm, 1 000–1 249 mm, ≥1 250 mm) to see if size distribution of captured snakes differed between trapping and spotlighting. These comparisons were analysed using Fisher's "exact" test to avoid potential inferential problems due to small cell sizes.

RESULTS

The average number of Brown Tree Snakes captured by each method during each month of the study, are summarized in Table 1. Using the mixed linear model analysis, we detected no influence on captures from trap placement (forest vs fence), by itself or as an interaction with capture method or month ($F \leq 3.63$, $p \geq 0.20$ in each case). However, an interaction was found for the number of captures between the method used (trap *vs* spotlight search) and time ($F = 15.8$, $df = 2,4$, $p = 0.013$). Captures by trapping remained substantially higher than from spotlight searches for each month, but the disparity decreased rapidly over time (Table 2), thus producing the interaction effect.

Table 1. Mean monthly Brown Tree Snake captures on Guam from November 1998 to January 1999 by spotlighting fencelines and trapping, with traps placed either on the forest edge (2 sites) paralleling the fences or on the fences (2 sites).

Trap Placement	Capture Method	Month		
		Nov	Dec	Jan
Fence	Trap	24.5	10.0	7.0
	Spotlight	8.5	5.0	4.0
Forest	Trap	38.0	16.5	15.5
	Spotlight	0.5	0.5	0.5

Table 2. Method-by-month interaction means for the number of Brown Tree Snake captured on Guam from November 1998 to January 1999 by spotlighting fences and trapping.

	Method	
	Trap	Spotlight
November	31.25	4.50
December	13.25	2.75
January	11.25	2.25

Table 3. Sizes and sex distribution of Brown Tree Snakes captured on Guam from November 1998 to December 1999 by spotlighting fences and trapping.

Capture Method	Sex	Least squares mean SVL (mm)	SE	Minimum SVL (mm)	Maximum SVL (mm)	% in each Gender
Spotlight	F	901	48.7	693	1 105	46%
Spotlight	M	893	46.8	813	1 255	54%
Trap	F	889	29.1	604	1 135	56%
Trap	M	945	29.8	583	1 585	44%

Table 4. Size and age class distribution of Brown Tree Snakes captured on Guam from November 1998 to December 1999 by spotlighting fences and trapping.

	% in each size class (mm)				% in each age class*	
Capture Method	<750	750–999	1 000–1 249	>1 250	Juvenile	Adult
Spotlight	3.7	77.8	14.8	3.7	66.7	33.3
Trap	11.3	68.2	18.2	2.3	65.9	34.1

*Brown Tree Snakes <950 mm were classified as juveniles and snakes >950 mm were classified as adults.

The SVL data were analysed only for November and December, as some data from January were lost when identification labels were separated from collection bags of snakes during cold storage before measurements were taken. Fortunately, November and December accounted for 80% of the captures. No differences in average size (Table 3) were detected between capture methods, sexes, or their interaction ($F < 1.05$, $p > 0.49$, in each case). Complementing these results are the results from the categorical data analyses. No differences were detected between capture methods in the distribution of captures over size classes (Table 4), age classes (Table 4), or genders (Table 3) ($p > 0.58$, in each case). We also examined the minimum size of snake of each gender captured by each method (Table 3). While these results are not suitable for comparative purposes, because the greater number of captures by trapping yielded greater opportunity to capture small snakes, the results demonstrated that each method would capture small snakes (<700 mm SVL).

DISCUSSION

This study has attempted to address a number of questions concerning trapping and spotlighting fences as control tools for reducing Brown Tree Snake populations. The findings should provide information valuable for optimally integrating the two control tools, as well as validating some issues about their application.

In the three month time frame of this study, trapping removed many more snakes each month than spotlight searches (Tables 1 and 2). Spotlighting presents a snapshot view of Brown Tree Snake activity on a fenceline at the time the spotlighting vehicle passes, whereas trapping represents a weekly accumulation of the Brown Tree Snakes attracted into traps. If logistically possible, multiple spotlight searches per night of fences might close the gap in total captures between the two methods. For this study, we removed snakes from relatively short fence segments. We should note that spotlight searches along longer stretches of fenceline would result in many more captures with only a small increase in effort, but similar increases in length of a trap line would increase the trapping effort proportionally. Spotlight searches as a control tool has not been researched nearly as extensively as trapping, leaving substantial potential for optimizing its application relative to available resources.

Captures by trapping tend to exhibit an exponential decay to a low, steady-state value (Engeman and Linnell 1998; Engeman *et al.*, in press). On the other hand, captures by spotlight searches of fences, as currently applied, already are at lower levels and exhibit only minimal declines in numbers. Fences may form convenient, linear travel pathways for Brown Tree Snakes (Engeman *et al.* 1999), perhaps in part to forage for geckos (Rodda 1992). Thus, fences may "draw" snakes from an appreciable distance down the fenceline. If this is true, then the two methods complement each other as ingredients of an integrated pest management programme on Guam. Also, if true, this suggests that intensive spotlight searches of fences as a useful option for capturing members of incipient Brown Tree Snake populations in prey-rich environments where trapping may be less effective than on Guam (Engeman *et al.* 1999).

We did not statistically detect a difference in captures between forest versus fence trap placements, but the data in Table 1 are suggestive that there could be a (minor) effect. Each month of the study the average number of captures for traps on the forest edge exceeded that for traps hung on the fence. Perhaps a study focused only on this aspect would define if such difference exists. In many areas, there may be no practical choice as to whether traps can be hung on a fence or on a forest edge, but often there is a choice, and traps frequently are placed on both the fences and forest edges. The number of Brown Tree Snake traps is a fixed resource that needs to be applied for maximal effect, and the point about where to hang them merits further clarification.

We found no evidence to indicate a size difference between Brown Tree Snakes captured in traps or captured while spotlighting fences, either on the basis of average size, size distribution, minimum size, or age class. This is an important point because existence of a size differential would have implications for the application of control methods, and the probability that some snakes could evade control measures. While we know of no other study that provides such immediate geographical comparisons between spotlighting and trapping, previous studies in different contexts have not been consistent with our results, nor with each other. In 1990–92, Rodda *et al.* (1999b) found differences between sizes of Brown Tree Snakes hand captured by spotlight from forest vegetation versus those captured by trapping, inferring that the then current trap designs preferentially captured medium- and large-sized snakes. Similar results occurred from a study in 1993–94 where Brown Tree Snakes captured in traps generally averaged larger than those captured by spotlighting the forest edge (E. Campbell III, pers. comm. re. unpubl. data).

There are several possibilities for reconciling the results from those studies with the those from the present study. First, the trapping data from those studies are from 1994 and earlier, and may not well-represent current trapping technology, which has since advanced considerably. Current trap technology using a customized design of trap with an advanced hinge-pin design for the one-way flaps (Linnell *et al.* 1998) could well be more adept at catching the smaller snakes and have lower escape rates. Second, the spotlighting captures in those studies were from the forest, rather than from fencelines, as in this study. One possibility for the different results may be that snakes using the fences are larger on average than the snakes found in the forest. Lastly, we should consider the flip-side of the inference that trapping had a bias towards larger snakes, and consider that hand capture by spotlighting the forest instead might have a bias toward smaller snakes.

Other results further complicate the picture about sizes of snakes captured by spotlighting forests versus trap captures. Rodda *et al.* (1999a) indicated that juvenile Brown Tree Snakes had a higher vulnerability (2.5–4 times) to capture by trapping than did adult Brown Tree Snakes. Recent capture data also indicate a higher probability of initial capture for juvenile snakes, but recaptures (if snakes are released) are more probable for adult snakes (J. Shivik, pers. comm.). These studies provide evidence that traps could be size-biased towards smaller snakes, rather than larger snakes. While our study found no concrete size differences between trap captured Brown Tree Snakes and those hand captured while spotlighting fences, the results indicated that trapping was at least as effective for capturing small (sub 750 mm) snakes as was spotlighting fences.

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REFERENCES

Campbell, E. W. III, Rodda, G. H., Fritts, T. H. and Bruggers, R. L., 1999. An integrated management plan for the brown treesnake (*Boiga irregularis*) on Pacific Islands. Pp. 423–35 *in* Problem Snake Management: Habu and Brown Treesnake Examples ed by G. Rodda, Y. Sawai, D. Chiszar and H. Tanaka. Cornell Univ Press. Ithaca, NY.

Engeman, R. M. and Linnell, M. A., 1998. Trapping strategies for deterring the spread of brown tree snakes (*Boiga irregularis*) from Guam. *Pac. Cons. Biol.* **4:** 348–53.

Engeman, R. M. and Linnell, M. A., in press. The effect of trap spacing on the capture of brown tree snakes on Guam. *J. Wildl. Res.*

Engeman, R. M., Linnell, M. A., Aguon, P., Manibusan, A., Sayama, S. and Techaira, A., 1999. Implications of brown tree snake captures from fences. *Wildl. Res.* **26:** 111–16.

Engeman, R. M., Linnell, M. A. Pochop, P. A. and Gamboa, J., 1998a. Substantial reductions of brown tree snake (*Boiga irregularis*) populations in blocks of land on Guam through operational trapping. *Internat. Biodegrad. Biodeterior.* **46:** 167–71.

Engeman, R. M., Linnell, M. A., Vice, D. S. and Pitzler, M. E., 1998b. Efficacy of the methods used in an integrated programme to deter the spread of brown tree snakes from Guam. *Proc. Aust. Vert. Pest Confer.* **11:** 435–40.

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

Fritts, T. H. and McCoid, M. J., 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., McCoid, M. J. and Gomez, D. M., 1999. Dispersal of snakes to extralimital islands: incidents of the brown treesnake (*Boiga irregularis*) dispersing to islands in ships and aircraft. Pp. 209–23 *in* Problem Snake Management: Habu and Brown Treesnake Examples ed by G. Rodda, Y. Sawai, D. Chiszar and H. Tanaka. Cornell Univ. Press. Ithaca, NY.

Fritts, T. H., McCoid, M. J. and Haddock, R. L., 1990. Risks to infants on Guam from bites of the brown tree snake (*Boiga irregularis*). *Amer. J. Trop. Med. Hygiene* **42:** 607–11.

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

Jordan, M. A. and Rodda, G. H., 1994. Identification of sex in Boiga irregularis: implications for understanding population dynamics in Guam. *J. Herpetol.* **28:** 381–84.

Linnell, M. A., Engeman, R. M., Pitzler, M. E., Watten, M. O., Whitehead, G. F. and Miller, R. C., 1998. An evaluation of two designs of stamped metal trap flaps for use in the operational control of brown tree snakes (*Boiga irregularis*). *The Snake* **28:** 14–18.

Littell, R. C., Milliken, G. A., Stroup, W. W. and Wolfinger, R. D., 1996. *SAS System for Mixed Models*. SAS Institute. Cary, NC.

McLean, R. A., Sanders, W. L. and Stroup, W. W., 1991. A unified approach to mixed linear models. *The American Statistician* **45:** 54–64.

Rodda, G. H., 1992. Foraging behaviour of the brown tree snake, *Boiga irregularis*. *Herpetological J.* **2:** 110–14.

Rodda, G. H., Fritts, T. H. and Campbell, E. W. III., 1999a. The feasibility of controlling the brown treesnake in small plots. Pp. 468–77 *in* Problem Snake Management: Habu and Brown Treesnake Examples ed by G. Rodda, Y. Sawai, D. Chiszar and H. Tanaka. Cornell Univ Press. Ithaca, NY.

Rodda, G. H., Fritts, T. H., Clark, C. S., Gotte, S. W. and Chiszar, D., 1999b. A state-of-the-art trap for the brown treesnake. Pp. 268–84 *in* Problem Snake Management: Habu and Brown Treesnake Examples ed by G. Rodda, Y. Sawai, D. Chiszar and H. Tanaka. Cornell Univ. Press. Ithaca, NY.

Rodda, G. H., Fritts, T. H., McCoid, M. J. and Campbell, E. W. III., 1999c. An overview of the biology of the brown treesnake in small plots. Pp. 44–80 *in* Problem Snake Management: Habu and Brown Treesnake Examples ed by G. Rodda, Y. Sawai, D. Chiszar and H. Tanaka. Cornell Univ. Press. Ithaca, NY.

SAS Institute, 1992. SAS Technical Report P-229 SAS/STAT Software: Changes and Enhancements. SAS Institute, Carey, North Carolina.

SAS Institute, 1996. SAS/STAT User's Guide. SAS Institute, Carey, North Carolina.

SAS Institute, 1997. SAS/STAT — Software Changes and Enhancements through Release 6.12. SAS Institute, Carey, North Carolina.

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

Savidge, J. A., 1988. Food habits of Boiga irregularis, an introduced predator on Guam. *J. Herpetol.* **22:** 275–82.

Vice, D. S., Linnell, M. A. and Pitzler, M. E., 1999. Summary of Guam's Outbound Cargo Process: Preventing the Spread of the Brown Tree Snake. Working Draft Report, USDA/APHIS/Wildlife Services, Guam District.

Winer, B. J., 1971. Statistical Principles in Experimental Design. McGraw-Hill, NY.

Wolfinger, R. D., Tobias, R. D. and Sall, J., 1991. Mixed models: a future direction. Pp. 1380–388 *in* Proceedings of the 16th SAS Users Group Conference. SAS Institute, Carey, North Carolina.