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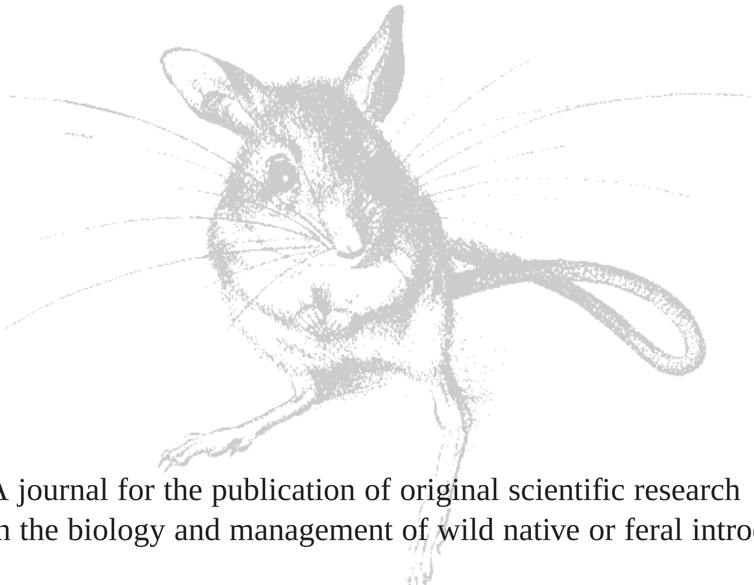
Wildlife Research

Volume 26, 1999



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Academy of Science

 Wildlife Research, 1999, **26**, 111–116

Implications of brown tree snake captures from fences

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Abstract

The capture of brown tree snakes (*Boiga irregularis*) from fence lines in the vicinities of air and sea ports is an important component of the integrated approach used for curtailing the dispersal of the species from Guam. Use of fences by brown tree snakes was characterised from over 600 captures of snakes during spotlight searches. Two construction designs of chain-link fences were searched, the difference being whether a horizontal bar or a steel cable was used to support the chain link on top. Both fence designs had snakes concentrated at the fence tops – fences having top bars produced 92% of captures on the top third of the chain link, the top bar, or the parallel barbed-wire strands above the fence; fences without top bars produced 82% of captures from the top third of the chain link or the wires above it. Most snakes were found in a horizontal position and no general trends were found through the night for when snakes ascend or descend the fences. To help concentrate snakes at the tops of fences for facilitating control efforts, we recommend the use of a horizontal bar to support the chain link on top, as well as the use of parallel barbed-wire strands above the fence. We discuss management implications for using searches of fences to control brown tree snakes and to detect new brown tree snake populations in other locales.

Introduction

The brown tree snake (*Boiga irregularis*) was introduced inadvertently to Guam in the 1940s (e.g. Rodda *et al.* 1992) and since has been responsible for the extirpation or substantial reductions of Guam's forest avifauna (Savidge 1987), fruit bats (Wiles 1987*a*, 1987*b*; Wiles *et al.* 1995), and native lizards (Rodda and Fritts 1992*a*). The snake also has caused problems for the local poultry industry (Fritts and McCoid 1991) and for electrical utilities (Fritts *et al.* 1987), and has become a public health risk (Fritts *et al.* 1990). Guam's importance as a shipping hub in the Pacific, coupled with the fragility of the other Pacific island ecosystems, has made the potential spread of the brown tree snake from Guam a serious concern (e.g. Fritts 1988).

Brown tree snakes are controlled on Guam at civilian and military air- and sea-port facilities, and other cargo-staging areas to curtail their potential dispersal to other vulnerable locations. Three primary control methods are employed: trapping (Engeman *et al.* 1998*a*, 1998*c*; Linnell *et al*. 1998), searches of cargo by detector dogs (Engeman *et al.* 1998*b*), and night-time capture during spotlight searches of fence lines. Most port areas and other cargo-staging locations are surrounded by extensive fence lines. Capturing brown tree snakes from fence lines is an efficient way to remove large numbers of snakes in the vicinity of ports (USDA/APHIS Wildlife Services data 1994–97). Understanding the use of fences by snakes could improve efficacy and efficiency of this control method.

Rodda (1991) described the fence-climbing behavior of brown tree snakes when released in the vicinity of a fence, and also provided initial insight on usage of fence components by brown tree snakes. With an aim to better defining fence usage by snakes and the construction and maintenance aspects of fences that best facilitate successful application of spotlight searches as a

10.1071/WR97110 1035-3712/99/010111

control tool, we report on data from over 600 captures of brown tree snakes during spotlight searches of fence lines.

Materials and Methods

We recorded information on snake captures from fence lines during routine operational control procedures conducted on Guam by the USDA/Wildlife Services program. To rapidly build a large descriptive database on captures from fence lines we used an active snake-removal program as our means of data collection. We conducted spotlight searches on fences at Won Pat International Airport (WPIA), Andersen Air Force Base (AAFB), Naval Activities (NAVACTS), Naval Computer and Telecommunications Area Master Station (NCTAMS), and the Naval Hospital (NH) during January–August 1996. All of these areas are surrounded by fences, and also have a network of fences within. Habitat adjacent to the fences was highly variable at each area, ranging from manicured lawns and landscaping to contiguous forest. All fences had suitable topography and cleared vegetation on one (and usually both) of the sides to permit vehicle access.

Searches were conducted by illuminating fences with 3.1 million lumen spotlights from slowly moving (8–16 kilometre per hour) vehicles between 2000 and 0400 hours. Most frequently, two people were in each vehicle, with one driving and one operating the spotlight, although sometimes only one person was in the vehicle. The fences searched were 2.4-m chain-link fences with 3 parallel strands of barbed wire on 45º outriggers above the chain-link portion. At all but one of the above five areas, a horizontal bar (5 cm diameter) supported the top of the chain link. Instead of a bar on top, the fences at AAFB were constructed with a 0.5-cm steel wire or braided cable woven through the top of the chain link to provide support. The total geographical areas encompassed in the search locations were 24 km^2 (59%) for fences with top bars and 17 km^2 (41%) for fences without top bars. Searches were part of routine control activities, and as such, search frequencies among the areas were similar and independent of fence design.

We recorded data according to the vertical fence component on which each snake was captured: the chain link, the horizontal support bar on top (where applicable), and each of the 3 barbed-wire strands. For data collected after April 1996 we further distinguished among the bottom, middle and top thirds of the chain-link portion. We also recorded for each capture: the direction the snake appeared to be headed (up, down, horizontal), the time of capture, and the date. We used the component data to infer the most likely portion of a fence on which to find a brown tree snake, and we used the movement direction data to examine the proportion of brown tree snakes ascending, descending and travelling along fences through the night.

We compared fence-component usage separately for the fence designs with Chi-square goodness of fit tests. We used Pearson's Chi-square statistic separately for each fence design to examine fence-component usage by hour through the night, direction of movement through the night, and direction of movement on the different fence components. We also examined differences in fence-component usage between the 2 fence designs with Pearson's Chi-square statistic. For situations where cell sizes were inadequate for Pearson's Chi-square to yield valid results we used Fisher's 'exact' test.

Results

We captured 408 (64%) brown tree snakes on fences with top bars at WPIA, NAVACTS, NCTAMS, and NH. We captured another 225 (36%) snakes on the fences at AAFB where the chain link was supported on top by a wire. Thus, capture totals were in proportion similar to the search areas by each fence type.

Fences with top bars

Captures of brown tree snakes were not distributed evenly among the fence components for fences with the top bars ($\chi^2 = 16.11$, d.f.= 2, $P = 0.0003$). We most frequently captured snakes on the horizontal support bar on the fence top (42%), followed by the barbed-wire strands above the top bar (33%) and, lastly, the chain-link portion (25%). Captures among the three barbed-wire strands also were not evenly distributed ($\chi^2 = 59.76$, d.f. = 2, $P < 0.0001$). The top strand held the most snakes (66% of the captures from the wires), followed by the middle and bottom wires (21 and 13%, respectively).

The relative proportion of captures from the different fence components varied among the hours of the night from 2000 to 0400 hours ($\chi^2 = 28.74$, d.f. = 14, $P = 0.011$), with the top bar showing a trend of increasing proportional usage towards the early morning hours (Table 1). The

Table 1. Percentage of brown tree snake captures using spotlights from different parts of fences through the hours of the night

	Fences with top bar Percentage found on:			Fences without top bar Percentage found on:	
Hour beginning:	link	bar	wires	link	wires
2000 hours	13	47	40	–	–
2100 hours	24	28	48	67	33
2200 hours	14	32	54	64	36
2300 hours	27	45	28	65	35
2400 hours	25	33	42	63	37
0100 hours	23	52	25	41	59
0200 hours	37	44	19	50	50
0300 hours	13	61	26	–	–

usage of the chain link fluctuated at relatively lower levels (13–37% of captures) through the night and wire usage tended to decrease towards early morning hours (Table 1). We captured most (71%) snakes in a horizontal position and this proportion differed little through the night (χ^2 = 2.76, d.f. = 7, P = 0.907), ranging from 68 to 83%. We did not detect differences through the night between the proportions that were ascending and descending (Fisher's 'exact' test, P = 0.938). Whether a snake was in a horizontal position versus ascending or descending varied according to the fence component upon which it was captured (χ^2 = 44.07, d.f. = 2, P < 0.0001). Snakes on the wires (91.27%) and the top bar (91.25%) were largely in the horizontal position, whereas snakes on the chain link were rarely in a horizontal position (13.54%), but were moving up or down.

Fences without top bars

We considered two general fence components: the wires and the chain link portion (snake usage of the small-diameter wire supporting the top of the chain link and the chain link through which it was woven could not be distinguished). Again, the fence components were not used equally (χ^2 = 4.88, d.f. = 1, P = 0.0272), with 58% of the captures from the chain link and 42% from the barbed wires above. This relative usage of wires was greater in the fences at AAFB where the top bar was absent than at the sites with top bars (χ^2 = 4.72, d.f. = 1, P = 0.030). As with fences with top bars, the wires were not used equally (χ^2 = 52.30, d.f. = 2, P < 0.0001), with the top wire again being most heavily used (72%), followed by the bottom and middle wires (16 and 12%, respectively).

We also found a majority (64%) of snakes in the horizontal position on the fences without a top bar, but this was a smaller proportion than for fences with a top bar (χ^2 = 3.37, d.f. = 1, P = 0.066). Again, we detected no differences through the night in the proportion of snakes that were ascending and descending (Fisher's 'exact' test, P = 0.979). Here, too, the directional heading of the snake was dependent on the fence component upon which it was captured (χ^2 = 37.47, d.f. = 1, P < 0.0001), with snakes on the wires almost always in a horizontal position (86.75%), and snakes on the chain link only half as likely to be found in a horizontal position (43.46%).

All fences

The top bar structure appeared to influence the vertical distribution of captures on the fences (χ^2 = 17.58, d.f. = 3, P = 0.001). Snakes located on fences with top bars tended to be more concentrated at the top, with 92% either on the wires or the top third of the chain link (including the top bar). Without the top bar, we found 82% of the snakes on the wires or top of the chain link. For both construction designs, we found few snakes near the bottom of the fence (2% on top-bar fences *v*. 4% on fences without top bars). More snakes were distributed in the middle portion of the chain link when the top bar was absent (15%) than when it was present (6%).

Discussion

The objective of the brown tree snake control program on Guam is to deter the spread of brown tree snakes to other locations through cargo flows. As such, most control efforts target port and other cargo-staging areas. Of the three control procedures applied in these areas, trapping and spotlighting of fences are used to remove snakes from their 'natural' environment. (Detector-dogs are used exclusively for cargo inspections prior to departure from Guam.) Trapping is highly effective at removing snakes (Engeman *et al.* 1998*a*, 1998*c;* Engeman and Linnell, in press), but is somewhat labour-intensive. Spotlight searches of fences are much less labour-intensive and require little preparation and planning. Therefore, they typically are conducted on an opportunistic basis in conjunction with other control activities (such as en-route to cargo inspections by detector-dogs). Even so, removal of snakes by this method has been accounting for an increasing proportion of the total number of snakes taken by operational control efforts. Fence-line searches accounted for 12.7% of 1735 snakes taken in the second half of 1994, 20.6% of 6108 in all of 1995, 35.9% of 4804 in all of 1996, and 38.7% of 941 in the first three months of 1997 (USDA/APHIS Wildlife Services data 1994–97). Fortunately, the areas targeted for control of brown tree snakes are largely surrounded by fences and usually have an additional network of fences within, which permits extensive application of spotlight searches of the fences as a control tool in addition to trapping. Searches of forest vegetation have yielded about the same number of snakes per kilometre as fence searches (Rodda and Fritts 1992*b*), but this method holds little potential as a practical operational control tool, as substantially more search time is required.

Regrettably, in some areas snake traps are heavily vandalised, or damaged by feral dogs and/or pigs, sometimes producing enough losses of traps that it is impractical to maintain a trapping program (M. Pitzler, personal communication). In these situations spotlighting fences may be the only effective control tool available for removing brown tree snakes from the area. It seems reasonable that regular spotlight searches of a fence surrounding a plot of land from which the brown tree snake population is to be removed may serve in a fashion similar to perimeter trapping (Engeman *et al.* 1998*c*; Engeman and Linnell, in press). Because brown tree snakes show considerable site fidelity (Tobin *et al.*, in press) and re-invade unoccupied areas slowly (Engeman and Linnell, in press), spotlight searches over time may produce significant population reductions in areas of extensive fence lines.

The chain-link fences constructed with a bar on top and parallel strands of wire above appear to concentrate snakes at the top of the fence, and thus increase the efficiency of spotlight searches. Fences subject to spotlight searches for snakes should be maintained free of vegetation and have a buffer of mowed vegetation between them and surrounding forest. Vegetation on the fence makes it difficult to observe snakes, while a mowed buffer between the fence and the forest facilitates searches from vehicles and promotes the fence-climbing behaviour observed by Rodda (1991).

It has generally been assumed that brown tree snakes use fences to forage for geckos (e.g. Rodda 1992), which are most commonly found on the vertical support poles and the top bar. On the other hand, the top bar and wires of the fences provide a continuous, stable pathway for snake movement. Ease of travel may be an important factor for use of fences by brown tree snakes which could yield further control applications. Spotlight searches of fences may be highly useful for detecting and capturing members of recently introduced populations. The efficacy for trapping snakes demonstrated on Guam could be much reduced in a prey-rich environment of an insular ecosystem to which brown tree snakes had been recently introduced (such as has been speculated to be the case on Saipan: McCoid *et al.* 1994). Routine spotlight searches along appropriately constructed and maintained fence lines could provide a fast and efficient means for detecting and removing brown tree snakes in a new environment.

Additional developments in control tools might take advantage of fence usage by brown tree snakes. Traps might be constructed with tense wires extending into the forest to enhance their ability to draw brown tree snakes to the traps. Likewise, wires or top bars of fences might guide the snakes into a delivery device for dermal toxicants recently under investigation (Brooks *et al.* 1998), and thus provide another tool for an integrated control program.

Acknowledgments

We thank all of the USDA/APHIS/Wildlife Services staff in Guam that kept careful capture records during the course of their control activities. M. W. Fall, R. L. Bruggers, D. S. Vice, P. J. Egan, and G. H. Rodda provided very helpful reviews of this manuscript. This research was conducted under funding provided to the U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Animal Damage Control Operations/Washington State Director's Office by the U.S. Department of Defense under DOD MIPR-064-95, 'Operational Control of Brown Tree Snakes in Guam'.

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Manuscript received 9 September 1997; accepted 7 July 1998

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