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First reported predation of fledgling Micronesian starlings (*Aplonis opaca*) by brown treesnakes (*Boiga irregularis*) on Guam*

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Abstract— The brown treesnake's (*Boiga irregularis* – BTS) invasion of Guam is a primary example of the devastation an invasive predator can have on island ecosystems. Its introduction following WWII caused the extirpation of most of the island's avifauna, although some native species have managed to persist in the presence of BTS, including a small population of Micronesian starlings (*Aplonis opaca*) on a military installation (Andersen Air Force Base – AAFB) in northeastern Guam. However, it remains unclear to what extent BTS predation continues to impact the population, particularly during the vulnerable post-fledging period. We report the first direct observations of BTS predation on Micronesian starling fledglings (n = 15). All 15 snakes that consumed starlings were in good to exceptional body condition and most were found in urban habitat within 100 m of the nest box of the depredated fledgling. Following the predation events, snakes tended to seek refugia and remain inactive for 4.0 ± 1.67 (mean ± SD) days. Our findings provide evidence of ongoing BTS predation of a native bird species in areas undergoing operational snake removal and indicate that current control efforts are not sufficient to prevent BTS from encroaching into urban areas on AAFB to access high quality prey resources such as birds and mammals. Our data on snake movement and activity patterns following predation events provide useful management information for future conservation and restoration efforts on Guam.

Introduction

Invasive predators are prominent drivers of species extinctions worldwide (Blackburn et al. 2004, Bellard et al. 2016, Doherty et al. 2016). Island species are particularly vulnerable due to their geographic isolation and a lack of coevolutionary history with invading predators (Martin et al. 2000, Blackburn et al. 2004). Following the introduction of the predatory brown treesnake (*Boiga irregularis* – BTS) to the island of Guam after WWII (Rodda et al. 1992) and its subsequent spread throughout the island, vertebrate populations, including 22 of 25 resident bird species (Wiles et al. 2003), experienced serious declines, extirpations, or extinction (Savidge 1987, Wiles 1987, Rodda & Fritts 1992). With the decline of Guam's birds and small mammals, both important prey for adult snakes, BTS have been forced to rely more heavily on smaller ectothermic prey (i.e. geckos and

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skinks; Savidge 1987, 1988). As a result, BTS body condition and mean body size has declined on an island-wide scale (Rodda & Savidge 2007). Nevertheless, individuals in urban habitats attain better body condition and larger body size relative to those in other habitats, suggesting that they can take advantage of the more energetically profitable endotherms that persist there, including birds and rodents (Savidge 1991, Siers et al. 2017).

A remnant population of Micronesian starlings (*Aplonis opaca*), one of the island's few extant native bird species, persists on Andersen Air Force Base (AAFB) in northeastern Guam (Wiles et al. 1995). Starlings on AAFB have adapted to living in the urban landscape and nest primarily in the tops of coconut palms, building cavities, concrete telephone poles and predator-proof nest boxes (Wiles et al. 1995, M.K., personal observation). The starling population appears to have increased in recent years to approximately 1,000 individuals (H.S.P. and M.K., unpublished data), an order of magnitude higher than the 50-100 individuals estimated in Wiles et al. (1995). This increase is presumably due at least in part to active snake removal efforts in the base's urban area. Predation pressure can impact different life-history stages unequally, with predation being a primary cause of mortality during the post-fledging period in many birds (Martin 1993, Cox et al. 2014). Understanding the effects of BTS predation on starling survival and population viability, particularly during the vulnerable post-fledging period – the time between fledging the nest and natal dispersal (Cox et al. 2014) – will be critical for informing future conservation efforts such as expanding the population to previously occupied areas on Guam and reintroducing other extirpated species. As part of an ongoing radio-telemetry study of post-fledging survival, we documented the first direct observations of BTS predation on fledgling starlings. Our observations provide information on behavior and ecology of BTS in urban areas that may help inform BTS control efforts to assist in the reintroduction of extirpated species on Guam.

Methods

Study Site and Study Species

Our study was conducted from April 2017 to October 2018 on AAFB, an 8,100-ha U.S. military installation located in northern Guam (13°35'02" N, 144°55'48" E). Undeveloped habitats on AAFB include secondary and mixed limestone forests. Urban areas are comprised of housing, administrative buildings and military infrastructure; common vegetation includes the tree species *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Cocos nucifera*, *Delonix regia*, and *Vitex parviflora*, a variety of other ornamental trees and shrubs, and maintained grassy areas. Guam experiences a wet season from July to November and a dry season from December to June (Siers et al. 2017).

Aplonis opaca is a medium-sized (~80 g) passerine bird species in the family Sturnidae and has a geographic distribution throughout the Mariana and Caroline Islands in Micronesia (Craig & Feare 2017). BTS are a rear-fanged snake species in the family Colubridae and have a native range that includes Australia, Papua New Guinea, and a number of islands in Melanesia; their non-native range is Guam (Fritts 1988). BTS are nocturnal and slender, facilitating capture of arboreal prey (Rodda et al. 1999), although some larger individuals forage on the ground, as they are too heavy to hunt in trees (Rodda et al. 1992). They employ both ambush and active foraging (Rodda et al. 1992) and kill prey via envenomation, direct swallowing or constriction (Chiszar 1990).

Transmitter Attachment and Radio-Telemetry

Fledglings in this study originated from predator-resistant nest boxes, which were part of a recently implemented effort to increase the starling population on AAFB (J.A.S., personal communication). Fledglings were marked during the nestling stage at 15 days post-hatching with a metal U.S. Fish and Wildlife Service band and a unique combination of Darvic color bands (Avinet, Inc.). At 23 days, they were fitted with a radio-transmitter (model BD-2, 1.8 g, Holohil Systems, Ltd.) using a leg-loop harness (Rappole & Tipton 1991). To minimize potential deleterious effects of transmitter attachment, we ensured that the combined weight of the transmitter, harness and bands weighed no more than four percent of each fledgling's body mass (Barron et al. 2010). To assess

fledgling survival, we re-sighted each fledgling once per day during the first two weeks following departure from the nest box, three times per week during the third and fourth weeks and once per week after the first month. Re-sighting activities consisted of using three-element Yagi antennas (Wildlife Materials, Inc.) and telemetry receivers (model R-1000, Communications Specialists, Inc.) to locate fledglings via transmitter signal and binoculars to confirm individual identity via color bands.

Snake Necropsy and Body Condition Estimates

We located BTS that had consumed fledglings during daily fledgling radio-telemetry survival checks. When possible, we hand-captured snakes during the day when they were visible. For the snakes encountered in inaccessible refugia, we returned each evening thereafter until snakes became active and were able to be captured. BTS were euthanized in accordance with the American Veterinary Medical Association Guidelines for the Euthanasia of Animals (Leary et al. 2013). During necropsies, we measured snout-vent length (SVL) and body mass (calculated as overall body mass minus prey mass), and assessed sex (Figure 1). Body condition was calculated as the ratio of an individual's body mass to expected mass given the individual's length, with a snake considered to be in poor body condition if BCI < 1 or good body condition if BCI > 1; expected mass was derived from a 4th-order polynomial regression of log(SVL) by log(body mass), based on a reference population of 1,804 BTS collected from 18 sites (stratified by season and 6 habitat types) throughout Guam from 2010 to 2012 by Siers et al. (2017).

Figure 1. Photo of BTS (11-Aug-17) necropsy showing A) Micronesian starling fledgling carcass being excised and B) a fledgling carcass with color bands. Photos taken by M. Kastner.

Results

We radio-tagged and monitored the survival of 43 starling fledglings in 2017 and 42 fledglings in 2018. Overall, we found 15 BTS (three in 2017, 12 in 2018) that had eaten fledglings (Table 1), 5 of which were female and 10 of which were male. Ten of the 15 fledglings were depredated early in the post-fledging period (i.e. within 3 days post-fledging) when they were still relatively sedentary. As a result, the vast majority (12 of 15) of snakes were located in urban habitat within 100 m from the nest box of the depredated fledgling (Table 1). However, the other three snakes were located in the urban habitat more than 1,000 m from the depredated bird's nest box – these three birds had already dispersed from the natal territory and were independent juveniles at the time of predation. All 15 BTS were in good (BCI > 1) to exceptional (BCI > 2) body condition when captured (Table 1). Most snakes became inactive for 4-6 days following ingestion of a starling fledgling (4.0 ± 1.67 days; mean ± SD), generally choosing large, hollow trees for refugia (Table 1).

Table 1. Brown treesnake (BTS) capture information and number of days post-fledging of the Micronesian starling consumed by BTS on Andersen Air Force Base, Guam. Characteristics of the 15 snakes that consumed starling fledglings include sex, snout to vent length (SVL), body mass, and body condition index (BCI).

Date of capture (days post-ingestion)	Sex	Days post-fledging	Distance from nest box (m)	Capture substrate	SVL (mm)	Body mass (g)	BCI
11-Aug-17 (5)	♀	1	41	*Ficus* sp.	1013	218.6	2.06
15-Oct-17 (1)	♀	3	46	ground (grassy ditch)	1210	380.1	1.70
22-Nov-17 (5)	♂	53	1,246	ground (rockpile)	1385	434.0	1.06
12-Jul-18 (4)	♂	1	48	*Casuarina equisetifolia*	1232	350.0	1.44
17-Jul-18 (4)	♀	1	98	*Casuarina equisetifolia*	1247	345.0	1.35
29-Jul-18 (5)	♂	1	23	*Casuarina equisetifolia*	1170	225.0	1.16
2-Aug-18 (1)	♂	1	67	*Delonix regia*	1010	180.0	1.72
9-Aug-18 (4)	♂	1	65	*Cocos nucifera*	1146	236.7	1.34
19-Aug-18 (1)	♂	8	64	*Vitex parviflora*	1204	250.0	1.14
28-Aug-18 (5)	♀	2	40	*Casuarina equisetifolia*	1062	222.0	1.73
29-Aug-18 (5)	♂	82	1,617	ground (drainage ditch)	1155	218.0	1.19
2-Sep-18 (5)	♀	1	38	*Casuarina equisetifolia*	1185	288.0	1.41
6-Sep-18 (6)	♂	1	36	*Ficus* sp.	1056	210.0	1.68
13-Sep-18 (5)	♂	16	78	*Casuarina equisetifolia*	1495	645.0	1.12
14-Sep-18 (4)	♂	63	1,289	ground (drainage ditch)	1494	830.0	1.44

Discussion

We report the first direct evidence of BTS predation on fledgling birds on the island of Guam. BTS are secretive, primarily arboreal and nocturnal (Rodda et al. 1999), making it difficult to monitor predation of birds by BTS in the wild. As a result, despite driving population declines and the eventual extirpation of nearly all of Guam's avifauna (Savidge 1987, Wiles et al. 2003), there are very few records of BTS predation on native birds of Guam in the literature with the exception of the Mariana swiftlet, *Aerodramus bartschi* (G.J. Wiles, personal communication). Savidge (1988) reported isolated incidents (n = 7) of BTS predation on Guam's native birds, including the only record of a BTS eating an adult Micronesian starling.

All 15 BTS we captured were in good (BCI>1) to exceptional (BCI>2) body condition, although these snakes varied greatly in body mass (range: 180-830 g) and SVL (range: 1010-1495 mm). BTS inhabiting urban environments have improved body condition and are generally larger than BTS living in other habitat types, which may be attributed to a higher abundance of large prey items, such as rodents and birds (Savidge 1988, 1991, Siers et al. 2017). A recent study of BTS predation on Mariana swiftlets reported superior body condition in BTS that had consumed swiftlets relative to a control group (P. Klug, personal communication). Furthermore, the majority of BTS captured with gut contents in proximity to swiftlet caves contained swiftlet remains, and these snakes had greater fat mass and more ovarian follicles than control snakes captured in the surrounding forest (P. Klug, personal communication). Thus, consuming avian prey appears to translate to better body condition. Nevertheless, it is important to highlight the broad range in body mass and SVL of the BTS we captured.

Operational snake control in this area consists of a perimeter at the forest/urban interface comprised of snake traps with live mouse lures and bait stations with dead neonatal mouse baits containing acetaminophen toxicant (Clark et al. 2018). Our results indicate that current snake control measures are not sufficient to fully prevent encroachment of BTS into urban areas where larger prey, such as starlings, nest and roost. BTS are either entering the urban area from adjacent forest to forage or are urban residents. The behavior of snakes following ingestion suggests the latter – all 15 BTS were captured in the urban area, and they generally chose refugia very close to depredated fledgling nest boxes. Similarly, Vice et al. (2005) found multiple introduced Eurasian tree sparrows (*Passer montanus*) at varying stages of digestion in the guts of BTS, suggesting that BTS may remain in food rich areas on successive nights. Finally, we have anecdotally observed the same BTS individual depredating consecutive clutches from the same nest box (H.S.P. and M.R.K., personal observations). Taken together, these results suggest that BTS may be residing in the urban area and even a few individuals could be having a disproportionately large impact on the starling population. We found 4-6 day periods of inactivity following ingestion of starling fledglings, almost identical to the 5-7 day periods found in experimental field assays (Siers et al. 2018). These long periods of inactivity, presumably when digestion is occurring, make BTS less detectable and could complicate suppression of snakes in prey-rich areas (Siers et al. 2018).

We demonstrate that, despite ongoing snake removal efforts on AAFB, BTS predation regularly occurs during the starling post-fledging period. Understanding the impact of BTS on the various life stages of native birds will be important for facilitating the expansion of the starling population and possible reintroduction of other extirpated native species in the presence of heavily suppressed BTS populations (e.g. applying landscape-scale aerial baiting as per Dorr et al. 2016 and Siers et al. in press). Developing control methods that target snakes in urban areas, where a number of bird species have found refuge (Wiles et al. 2003), may be a key component of future avian conservation efforts on Guam.

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References

Barron D.G., J.D. Brawn & P.J. Weatherhead. 2010. Meta-analysis of transmitter effects on avian behaviour and ecology. Methods in Ecology and Evolution 1: 180-187.

Bellard, C., P. Cassey & T.M. Blackburn. 2016. Alien species as a driver of recent extinctions. Biology Letters 12: 20150623.

Blackburn, T.M., P. Cassey, R.P. Duncan, K.L. Evans & K.J. Gaston. 2004. Avian extinction and mammalian introductions on oceanic islands. Science 305: 1955-1958.

Chiszar, D.A. 1990. Behavior of the brown tree snake, *Boiga irregularis*: a study in applied comparative psychology. *In* D. Dewsbury (ed), Contemporary issues in comparative psychology, pp. 101-123. Sinauer Associates, Sunderland, MA.

Clark, L., C. Clark & S. Siers. 2018. Brown Treesnakes: methods and approaches for control. *In* W.C. Pitt, J. C. Beasley & G. W. Witmer (eds). Ecology and management of terrestrial vertebrate invasive species in the United States. CRC Press, Boca Raton, FL. pp. 107-134.

Cox, W.A., F.R. Thompson III, A.S. Cox & J. Faaborg. 2014. Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. Journal of Wildlife Management 78: 183-193.

Craig A. & C. Feare. 2017. Micronesian starling (*Aplonis opaca*). *In* J. A. del Hoyo, A. Elliott, J. Sargatal, D.A. Christie & E. de Juana (eds), Handbook of the birds of the world alive. Lynx Edicions, Barcelona, Spain.

Doherty, T.S., A.S. Glen, D.G. Nimmo, E.G. Ritchie & C.R. Dickman. 2016. Invasive predators and global biodiversity loss. Proceedings of the National Academy of Sciences of the United States of America 113: 11261-11265.

Dorr, B.S., C.S. Clark & P.J. Savarie. 2016. Aerial application of acetaminophen-treated baits for control of brown treesnakes (RC-200925; NWRC Study Number: QA-1828). Final Report, U.S. Department of Defense ESTCP. 62 pp.

Fritts, T. H. 1988. The Brown Tree Snake, *Boiga irregularis*, a Threat to Pacific Islands. U.S. Fish and Wildlife Service 88. Washington, DC: U.S. Fish & Wildlife Service. 36 pp.

Leary, S., W. Underwood, R. Anthony, S. Cartner, D. Corey, T. Grandin, C.B. Greenacre, S. Gwaltney-Bran, M.A. McCrackin & R. Meyer. 2013. AVMA Guidelines for the euthanasia of animals, 2013 Edition. American Veterinary Medical Association, Schaumburg, IL.

Martin, T.E. 1993. Nest predation and nest sites. BioScience 43:523–532.

Martin, J.L., J.C. Thibault & V. Bretagnolle. 2000. Black rats, island characteristics, and colonial nesting birds in the Mediterranean: consequences of an ancient introduction. Conservation Biology 14: 1452-1466.

Rappole, J.H. & A.R. Tipton. 1991. New harness design for attachment of radio transmitters to small passerines. Journal of Field Ornithology 62: 335–337.

Rodda, G.H. & T.H. Fritts. 1992. The impact of the introduction of the brown tree snake, *Boiga irregularis*, on Guam's lizards. Journal of Herpetology 26: 166-174.

Rodda, G.H. & J.A. Savidge. 2007. Biology and impacts of Pacific island species. 2. *Boiga irregularis*, the brown tree snake (Reptilia: Colubridae). Pacific Science 61: 307-324.

Rodda, G.H., T.H. Fritts & P.J. Conry. 1992. Origin and population growth of the brown tree snake, *Boiga irregularis*, on Guam. Pacific Science 46: 46-57.

Rodda, G.H., T.H. Fritts, M.J. McCoid & E.W. Campbell III. 1999. An overview of the biology of the brown treesnake (*Boiga irregularis*), a costly introduced pest on Pacific islands. *In* Rodda, G.H., Y. Sawai, D.A. Chiszar & H. Tanaka (eds), Problem snake management: The habu and the brown treesnake, pp. 44-80. Cornell University Press, Ithaca, NY.

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.

Savidge, J.A. 1991. Population characteristics of the introduced brown tree snake (*Boiga irregularis*) on Guam. Biotropica 23: 294-300.

Siers, S.R., W.C. Pitt, J.D. Eisemann, L. Clark, A.B. Shiels, C.S. Clark, R.J. Gosnell & M.C. Messaros. In press. In situ evaluation of an automated aerial bait delivery system for landscape-scale control of invasive brown treesnakes on Guam. *In* D. Veitch (ed), Proceedings of the 2017 island invasives conference. IUCN, Gland, Switzerland.

Siers, S.R., J.A. Savidge & R.N. Reed. 2017. Quantile regression of microgeographic variation in population characteristics of an invasive predator. PLoS ONE 12: e0177671.

Siers, S.R., A.A. Yackel Adams & R.N. Reed. 2018. Behavioral differences following ingestion of large meals and consequences for management of a harmful invasive snake: A field experiment. Ecology and Evolution (in press). doi: 10.1002/ece3.4480.

Vice, D.S., D.L. Vice & J.C. Gibbons. 2005. Multiple predations of wild birds by brown treesnakes (*Boiga irregularis*) on Guam. Micronesica 38: 121-124.

Wiles, G.J. 1987. Current research and future management of Marianas fruit bats (Chiroptera: Pteropodidae) on Guam. Australian Mammalogy 10: 93-95.

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

Wiles, G.J., J. Bart, R.E. Beck Jr. & C.F. Aguon. 2003. Impacts of the brown tree snake: patterns of decline and species persistence in Guam's avifauna. Conservation Biology 17: 1350-1360.

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