Micronesica Suppl. 3: 63–69, 1991

Brown tree snake (*Boiga irregularis*) on Guam: a Worst Case Scenario of an Introduced Predator

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Abstract—*Boiga irregularis* was probably introduced on Guam a little over forty years ago. Since then, the snake population has become very dense and has been responsible for enormous biological, economic, and cultural damages. Because of severe reductions in vertebrate biodiversity, changes in insect densities and diversity and vegetational shifts should occur.

Introduction

The brown tree snake (*Boiga irregularis*) was probably introduced to Guam, Mariana Islands, in the late 1940's (Fritts 1988) via surface cargo movements of surplus U. S. military equipment. The most likely source population is Manus Island (Admiralty Islands), north of Papua New Guinea (T. Fritts, pers. comm.). Reports of *B. irregularis* four to eight feet in length began in the early and mid 1950's (Elvidge 1955). These sightings were from the vicinity of the village of Santa Rita, adjacent to the U. S. Naval port facility, and probably represented several generations of snakes (Fritts 1988).

Until relatively recently, there was little documentation of the spread of *B. irregularis* on Guam. This may be due to the secretive behavioral characteristics of the snake (nocturnal and arboreal). However, during the 1960's and 1970's, the avifauna underwent significant spatial and density changes. Two causative agents were explored: disease and pesticides, but both failed to explain the observed avifaunal changes (Grue 1985, Savidge 1986). Savidge (1987a) demonstrated that *B. irregularis* was the primary culprit in the demise of virtually the entire native forest-dwelling avifauna. This research spawned numerous popular articles (Anonymous 1989, Carey 1988, McCoid 1989a, Montgomery 1988, Pimm 1987, Quammen 1985, Rauzon 1989, Savidge 1987b, and Teodosio 1987) and opened the door for continued research into the remarkable role which the introduction of a single species of vertebrate has had on Guam.

The impact of the brown tree snake on Guam extends beyond that of the conspicuous biological impact. Significant negative effects have also been observed in virtually all aspects of life on Guam (cultural, economic, and health). All these negative impacts can be examined on two levels: primary and secondary effects.

Primary Effects

BIOLOGICAL

Native vertebrate biodiversity has been heavily impacted. Eight species of forest-dwelling birds have been extirpated from Guam due primarily to *B. irregularis* predation (Table 1) (Aguon 1991). Three additional species of native forest-dwelling birds persist on Guam, but have suffered serious population and range reduction (Table 1). Five species of introduced birds have shown either declining or stationary population levels (Table 1) (Beck et al. 1988).

Wiles (1987) indicated that *B. irregularis* may be a factor in the decline of the native frugivorous, nectivorous Mariana fruit bat (*Pteropus m. mariannus*). Five species of introduced small mammals occur on Guam (three rats, *Rattus rattus, R. norvegicus,* and *R. exulans*; a mouse, *Mus musculus*; and a shrew, *Suncus murinus*) and were formerly widespread. While no empirical data have been published, these introduced mammals currently appear to be relatively restricted to urban areas and may be at lower population densities than were formerly exhibited (pers. obs.). Savidge (1988) showed that *B. irregularis* regularly consumed these introduced mammals. The snake may be a factor in the spatial restriction of these species on Guam. Larger snakes now occur in urban as compared to non-urban locations and snakes greater than 125 cm snout-vent length are almost always urban (M. McCoid, unpub. data). These phenomena may be related to prey availability.

Besides the avian and mammalian reductions in population and diversity, evidence suggests that *B. irregularis* has also negatively impacted at least two

Table 1. List of native and introduced urban and forest-dwelling birds that have been impacted by *B. irregularis*. 1=extinct, 2=extirpated on Guam, other populations exist, 3=extinct in the wild, captive populations exist, 4=rare to uncommon on Guam, other populations exist, and 5=introduced.

Species	Common name	Status	Trophic Level
Rallus owstoni	Guam Rail	3	omnivore
Ptilinopus roseicapillus	Mariana fruit dove	2	frugivore
Gallicolumba x. xanthonura	white-throated ground dove	2	frugivore
Halcyon c. cinnamomina	Micronesian kingfisher	3	insectivore/carnivore
Rhipidura rufifrons uraniae	rufous-fronted fantail	1	insectivore
Myiagra freycineti	Guam flycatcher	1	insectivore
Zosterops c. conspicillata	bridled white-eye	1	insectivore
Myzomela cardinalis	cardinal honeyeater	2	nectivore/insectivore
Corvus kubaryi	Mariana crow	4	omnivore
Aplonis o. opaca	Micronesian starling	4	omnivore
Aerodromus vanikorensis bartschi	island swiftlet	4	insectivore
Columba livia	rock dove	5	granivore
Streptopelia bitorquata	Philippine turtle dove	5	granivore
Passer montanus	Eurasian tree sparrow	5	granivore
Lonchura malacca	chestnut mannikin	5	granivore
Dicrurus macrocerus	black drongo	5	insectivore

species of native reptiles. Sabath (1981) recorded both *Perochirus ateles* and *Gehyra oceanica* as conspicuous members of the herpetofauna of Guam in 1968–69. Since then, both species have been extirpated from Guam. Both geckos persist in relatively large numbers on Cocos Island, a barrier reef island 2.5 km SW of Guam. Cocos Island remains free of *B. irregularis* at this time.

CULTURAL

Until the introduction of *B. irregularis*, the only other snake in the Mariana Islands was the blind snake, *Ramphotyphlops braminus*. This latter species is a small, fossorial, rarely encountered form that is commonly mistaken for an earthworm. For this reason, the Mariana Islands were characterized by the indigenous peoples as snake-free. The infestation and proliferation of *B. irregularis* has resulted in concerns about many aspects of life on Guam. Accommodations in human life styles are having to be made to prevent bites (see below), provide a snake-free habitation and workplace, and protect pets and livestock (see below), all of which, until forty years ago, were not necessary.

ECONOMIC

These nocturnal and highly arboreal snakes routinely climb guy-wires on power poles, cross transmission lines, and enter transformers. Because of these behaviors, the brown tree snake has been responsible for enormous economic damage due to power outages (Fritts et al. 1987). These problems continue to the present.

Fritts & McCoid (1991) showed that almost 50% of the people that raised domesticated fowl were aware of some level of predation by brown tree snakes. It is difficult to assign a monetary value to this type of predatory pressure, but if a subsistence farmer is relying on chickens for a portion of his family diet, then the effects could be economically detrimental. Both Fritts (1988) and Fritts & McCoid (1991) also found that pets and cage birds suffered mortality due to *B. irregularis*.

HEALTH

The genus *Boiga* is recognized as rear-fanged and venomous (Cogger 1988). While the potential for serious problems associated with a bite from *B. irregularis* have been recognized (Fritts 1988), it wasn't until very recently that the effects of bites were documented (Fritts et al. 1990). The responses to bites appear to be anaphylactoid and in two of the cases involving human infants, had they not been at a hospital, the likelihood of death existed (Fritts et al. 1990). Since the reaction to the bite is anaphylactoid, the possibility exists that certain adults may also be more susceptible to severe reactions.

Secondary Effects

At this time, secondary effects are difficult to discern. This is due to a number of confounding factors. For example, few historical comparative or baseline data

exist on insect and plant abundances and distributions on Guam. Moreover, Guam is currently experiencing enormous economic development. Large tracts of land are undergoing conversion to urban situations, further clouding the documentation of the distribution and biodiversity of the existing fauna and flora. Despite these factors, some predictions can be made regarding the long-term effects of altering the biodiversity of an island ecosystem.

FAUNAL CHANGES

Table 1 lists the avifauna that have been impacted by the introduction of *B. irregularis* and their trophic roles. Six of the eight extirpated species of birds were either wholly or partially classified as insectivores. The only remaining avian insectivore (*A. vanikorensis*) has a population estimate of approximately 450 (G. Wiles, pers. comm.). The two native omnivorous birds that remain on Guam have low (*A. opaca*, n=500) to very low (*C. kubaryi*, n=50) populations and are distributionally localized (G. Wiles and J. Guerrero, pers. comm.). The introduced birds include only one insectivore (*D. macrocerus*) and this species currently exhibits only localized distribution and low population levels (G. Wiles, pers. comm.).

Based on population estimates supplied by Aguon (1991) (and references therein) for the native insectivorous or omnivorous birds that are extinct, extirpated, or at low levels, and assuming that Guam harbored at least as many birds as islands of smaller surface area in the northern Mariana Islands, a conservative estimate of the total number of insectivores/omnivores that are missing from Guam is 300,000 individuals. Additionally, an unknown number of insectivorous geckos (see above) are missing from Guam. If this scenario is correct, then considerable increases or changes in insect abundance and diversity should be expected.

FLORAL CHANGES

If a plant community is dependent upon frugivorous, nectivorous, or granivorous vertebrates to enhance the continuity of that community by providing mechanisms for seed dispersal (postzygotic) or pollination (prezygotic), then the prediction on Guam would be that floral changes should also be expected.

Table 1 shows that the two species of native birds that were frugivores no longer occur on Guam. Additionally, four species of introduced granivores have restricted ranges on Guam and occur in low densities (Beck et al. 1988). Potential pollinators were *M. cardinalis, Z. conspicillata,* and *P. m. mariannus* remains (n=400-600; G. Wiles, pers. comm.). While *Z. conspicillata* is classified as an insectivore, this species frequently foraged in flowers and may have acted as a pollinator. These facilitators in the maintenance of floral diversity and abundance are no longer functioning at the levels that they were. Because of this, species of plants that utilized these dispersal mechanisms on Guam should exhibit contractions in distribution. This may be difficult to test because of herbivory by introduced vertebrates, such as deer, pigs, and goats. However, both Muniappan (1988) and Denton et al. (1991) postulated that the range restriction of *Lantana*

camara on Guam was due to the absence of frugivorous birds. This might be the first demonstrable vegetational effect of the removal of a facilitator of dispersal by *B. irregularis* predation.

Future of *Boiga* on Guam

It is likely that *B. irregularis* will persist on Guam indefinitely. This is despite the facts that almost all native birds have been extirpated and introduced small mammals have been restricted to primarily urban areas. The majority of *B. irregularis* on Guam are three to four feet (90-120 cm) in total length (Fritts 1988). Savidge (1988) demonstrated that this size and smaller were consuming primarily lizards, which McCoid (1991) found belonged primarily to three introduced species. The reproductive characteristics of lizards on Guam, both native and introduced, indicate that these species have sustainable yield as prey for *B. irregularis* (McCoid 1989b). Because of this, Guam will remain a source population for further infestations in the Pacific Basin.

Inter-island Movements

Boiga irregularis has proven adept at moving from Guam to other islands. Fritts (1987, 1988) reported that *B. irregularis* has shown up on Oahu, Wake Island, Kwajalein Island, Diego Garcia Atoll, and Saipan (M. McCoid & D. Stinson, unpub. data). Sightings (but no specimens) of snakes are also reported to Tinian, Kauai (Telfer 1989), and Pohnpei. These inter-island movements are occurring via civilian and military aircraft and surface cargo shipments because Guam is a commercial and military shipping hub. The economic development that the Pacific Basin is currently enjoying will probably continue into the 21st century and will generate continued high levels of commercial and military intercourse. Because of this, off-island movements of *B. irregularis* will continue to occur and will increase the likelihood of infestation on islands that currently engage in military and economic traffic with Guam.

Control and Containment

At this time, no prescribed chemical or mechanical methods exist to prevent infestation of cargo or aircraft by *B. irregularis*. Currently, the most powerful weapon in the arsenal against the brown tree snake is education. The Government of Guam (Division of Aquatic and Wildlife Resources), U. S. Department of the Interior (Fish and Wildlife Service), and the U. S. Department of Defense are actively engaged in training of personnel to intercept *B. irregularis* in high-risk situations (port and airport facilities) on Guam and other islands in the Pacific community judged to be at risk for infestation. Recent evidence suggests that these efforts may be successful. The *B. irregularis* from Saipan (M. McCoid and D. Stinson, unpub. data) was found by an airline employee who was aware of the threat because of educational materials funded by the U. S. federal monies.

Within the past two years, 15 snakes have been intercepted by U. S. military security or customs personnel in high-risk situations on Guam (in or on aircraft, in hangers, on runways, or on cargo) (Petty Officer A. Hill, U. S. Military Customs, COMNAVMAR, personal communication). All military customs personnel assigned to Guam are required to include a seminar on *B. irregularis* in their training regimen.

It is clear though, that these efforts will not be enough to prevent the spread of the brown tree snake to other islands in the Pacific. Population densities of *B. irregularis* are high (T. Fritts, pers. comm.) and it is unlikely that all snakes will be intercepted. Because of this, the next phase of brown tree snake control should involve the development of chemical and mechanical means for more effective control and local eradication in specific high-risk sites.

Acknowledgements

I thank A. Hill for sharing information on U. S. military efforts in snake control. Both R. Hensley and C. Aguon read and commented on this manuscript. Co-workers R. Beck, G. Wiles, and J. Guerrero shared their thoughts. Support for this paper was provided by the Endangered Species Conservation Program, Project E-4.

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