

# DEMISE OF AN INSULAR AVIFAUNA: THE BROWN TREE SNAKE ON GUAM

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**Abstract:** Over the last two decades the native forest birds of Guam have undergone a precipitous population decline. Nine of the 11 species of native forest birds that were resident when the decline began have been extirpated. Five of the species that have become extinct in the wild are endemic at the species or subspecies level. The major cause of the decline has been attributed to predation by the introduced brown tree snake (*Boiga irregularis*), a nocturnal, arboreal predator. The snake population has irrupted on Guam and reached high densities, and it may be accidentally carried to other islands in the Pacific causing similar ecological disasters. Actions are now being taken to prevent the spread of the snake to other islands, to study methods to control the snake, and to save the few Guam birds remaining.

Outside of Guam, the birds of Micronesia have historically fared well (Engbring and Pratt 1985). Of the approximately 80 resident species representing 220 resident populations among the major island groups, only two are known to have become extinct over the last 150 years: the Kosrae rail (*Porzana monasa*) and the Kosrae mountain starling (*Aplonis corvina*). Within the last two decades the resident birds on the island of Guam have undergone a precipitous population decline (Jenkins 1983, Engbring and Ramsey 1984, Savidge 1984), and nine birds have been extirpated. Such a decline has not been documented elsewhere in the Pacific, with the possible exception of the loss of Hawaiian birds around the turn of the century. Although the native forest birds have been most severely affected, birds from a variety of guilds have declined. A number of theories have been proposed as reasons for the decline, including pesticides, disease, habitat loss, and predation by the introduced brown tree snake (*Boiga irregularis*). Studies conducted by the Guam Division of Aquatic and Wildlife Resources clearly implicate the snake as the major cause for this population crash (Savidge 1986, 1987).

### STUDY AREA

Guam, the southern-most island of the Mariana Archipelago, is the largest and most developed of all islands in Micronesia and constitutes the de facto capital for this region of the Pacific. Guam is located in the tropical western Pacific, nearly equidistant from Japan to the north, the Philippines to the west, and New Guinea to the south. The island is a U.S. Territory, and several large Naval and Air Force bases have been constructed and maintained on Guam since the end of World War II.

Guam is 49 km long, 7-15 km wide, and has an area of 550 km<sup>2</sup>. A narrow, central waist separates the island into a northern, fairly level, limestone plateau, and a southern, more mountainous region of volcanic origin. The northern limestone plateau averages 100-200 m in elevation, while in the south one mountain reaches 400 m elevation. Before the arrival of humans, Guam was thought to be nearly entirely covered by tropical broad-

leaf forests (Fosberg 1960). Today the island is greatly dissected by savannas, fields, urban areas, military installations, and roads. Typically, the northern portion of Guam supports a diverse forest, whereas the southern portion harbors savannas on the exposed uplands and ravine forest in the sheltered valleys. The extensive savannas in southern Guam are thought to be largely the result of clearing and burning by humans. The climate is tropical marine. It is warm and moist with minimal variation in temperature. Annual rainfall is about 250 cm, most of which falls during the wet season from July through November.

### AVIFAUNA

One hundred and two species of birds have been recorded from Guam (Pyle and Engbring 1985, Wiles et al. 1987). Seventy-two of these birds are migrant or vagrant species mostly from the Old World, and 30 are resident species of which 22 are native and 8 are introduced (Table 1). Of the 22 native, resident species, 12 are forest birds, 5 are wetland birds, 4 are seabirds, and the remaining bird is a swiftlet. Most forest birds of Guam are generalists and exhibit few of the specialized adaptations that are evident in isolated, insular communities such as Hawaii or the Galapagos. Historically, and until the early 1960's, most resident species of forest birds were relatively common throughout the forests of Guam (Seale 1901, Baker 1947, Marshall 1949, Jenkins 1983).

Four species of indigenous Guam birds, the Micronesian megapode (*Megapodius laperouse*), Mariana mallard (*Anas platyrhynchos*, a subspecies of mallard endemic to the Marianas), white-browed rail (*Poliolimnas cinereus*), and wedge-tailed shearwater (*Puffinus pacificus*), became extinct before the arrival of the brown tree snake, and the cause of these extinctions appears to be unrelated to the current decline. Since about 1965, nearly all birds, especially forest birds, have suffered a tremendous decline in numbers and range (Jenkins 1983, Engbring 1983, Engbring and Ramsey 1984). The decline has affected birds in a variety of guilds, including insectivores, nectivores, omnivores, fructivores, sea-



and documented nearly 20 years ago (Jenkins 1983), the snake was not clearly implicated until recently (Savidge 1987). Various factors have been suggested as the cause for the decline including avian disease, introduced predators such as the brown tree snake, rats, cats, and dogs, competition with introduced birds, pesticides, hunting, and habitat loss (Maben 1982, Jenkins 1983, Savidge 1987). Since 1981, studies have been conducted on pesticides, disease, and the snake. There has been no evidence to implicate pesticides (Grue 1985) or disease (Savidge 1986). Studies on the snake, however, clearly point toward it as the decimating factor (Fritts 1984, Fritts and Scott 1985, Savidge 1986, 1987).

### THE BROWN TREE SNAKE

The native range of the brown tree snake extends from eastern Indonesia through New Guinea, the Solomon Islands, and northern Australia (Worrell 1963, Cogger 1975, McCoy 1980). Based on the scale pattern of snakes examined by Fritts, snakes on Guam are most similar to those of the Admiralty Islands of northern Papua New Guinea, and this is possibly the area from which snakes were introduced to Guam. Several military bases were established in the Admiralty Islands during World War II, and it is suspected that the snake was accidentally introduced to Guam as a stowaway aboard military cargo. Unidentified snakes, probably brown tree snakes, were recorded on Guam in the late 1940's. The first documented records of brown tree snakes from Guam are from the early 1950's.

The snake is believed to have first arrived at and colonized south-central Guam (Savidge 1987). From here, as documented by interviews with residents and declines in forest bird species, the snake became conspicuous first throughout the south and then toward northern Guam (Savidge 1987). Although scattered snakes have showed up in various parts of Guam prior to this general spread, it is the large irruption or general spread that appears to have been the cause for the progressive extermination of bird populations from one area to the next.

### Habits and Biology

The brown tree snake is a rear-fanged, mildly venomous snake that is a nocturnal, arboreal predator. It is highly adaptable and commonly forages on the ground as well as in trees. Although the snake is aggressive and will bite if disturbed, the bite is not dangerous to adult humans. The snake is long and slender and can grow up to 2.4 m in length. It has a wide gape and the ability to distend its body to accommodate large prey. The snake is an exceptional climber. The long slender body and prehensile tail facilitate vertical and horizontal reaches from one limb to another across gaps in the forest canopy.

This not only helps the snake move from tree to tree in search of prey, but also enables it to squeeze through tiny spaces or up into the rafters of houses or warehouses.

### Habitat

Although the brown tree snake has been found in virtually all habitats and in nearly every conceivable situation on Guam, it is typically found in or around forests or brushy vegetation. Most forests on Guam are highly fragmented by roads, open fields, and urban or residential areas. Snakes are likely to be found in these areas wherever there is adjacent brush or forest. Extensive savannas, wetlands, and urban areas are habitats not favored by the snake, and snake densities in these areas are generally low. Because the snake is nocturnal it can easily escape detection by humans. During the day it seeks seclusion from heat and bright light. Normally it finds hiding places in hollow trees, crowns of palms, rocky cliffs, caves, and other natural features that provide dense shade and moderate temperatures. However, when it occurs in areas close to human settlements, hiding places can be drain pipes, rafters of buildings, vehicles, and a host of other man-made objects.

### Food Habits

The brown tree snake is able to take a wide variety of prey items, which it detects by both visual and olfactory cues (Chiszar et al. in press a and b). The snake often wraps its body around prey to immobilize it while chewing on the animal to inject venom with the teeth located in the back of the mouth. The snake feeds on a variety of prey items in its native range, including geckos, small mammals, birds, and bird eggs (Worrell 1963, Cogger 1975, McCoy 1980). In Papua New Guinea the snake regularly takes eggs and chicks, but rats and mice are the preferred food (Parker 1983). On Guam, the snake likewise forages on a variety of prey items, including birds, bird eggs, small mammals, skinks, anoles, geckos, and lizard eggs (Savidge 1986). Because most native birds have disappeared on Guam, birds and bird eggs found in snakes are usually domestic poultry, caged birds, and other domesticated or introduced species (Savidge 1986, 1988). In areas away from human habitation on Guam, where birds are rare or non-existent, the snake primarily eats a variety of lizards (Savidge 1988).

### Density

Observation and trapping studies have found exceptionally high snake densities on Guam. More snakes were caught per hour by experienced snake collectors on Guam (Fritts and Scott 1985) than in the rain forests of the Amazon Basin of Ecuador where 51 species of snakes occur in sympatry (Duellman 1978). Night collecting for snakes on Guam may be as much as eight

times more effective than in the Amazon where the snake fauna is highly diverse. Based on a comparison of trap success in peripheral versus interior traps, Savidge (1986) proposed a conservative estimate of 1,600 snakes per km<sup>2</sup> in one area.

#### Natural Mortality on Guam

The snake has few natural predators on Guam, and none of those are known to be major sources of mortality. Feral pigs and cats may sometimes take snakes (Fritts 1984), and the monitor lizard (*Varanus indicus*) is known to take an occasional snake (G. Wiles, pers. comm.). A few snakes are run over by traffic as they cross roads, and some are electrocuted as they crawl among electric power lines.

#### Scenario of Decline

There are no native snakes on Guam, except for the harmless blind snake (*Rhynchotyphlops braminus*). The Guam avifauna, having evolved in a snake-free environment, was therefore easy prey for the exotic brown tree snake. The cosmopolitan feeding habit of the snake allows it to easily switch prey types and maintain high population levels even after preferred food items are reduced in numbers (Savidge 1987, 1988). Thus, on Guam, high snake densities were maintained, and the snake continued to take endangered birds as they were encountered until the most vulnerable bird species became extinct. The abundance of lizards as a prey base for young and subadult snakes ensured the survival of the snake population even after bird and mammal populations plummeted. It was the adaptability of the snake that caused the tremendous decline and ultimate extinction of birds on Guam.

The chronology of the disappearance of birds from the central and southern parts of Guam before the northern region, and the relatively similar pattern of when snakes became conspicuous to island residents in various regions of the island (Savidge 1987) may be more reflective of when snake populations soared to extremely high levels than of the first dispersal and colonization of various regions. Snakes were known to be at Ritidian Point on the extreme northern point of the island as early as 1968 (R. Crombie, pers. comm.), but were judged to have irrupted in this region 12-15 years later by Savidge (1987). Thus, snakes were present on northern Guam for up to 15 years before they became obvious and caused birds to disappear.

As birds declined from one area after another on Guam, the smaller birds were the first to disappear (Pratt et al. 1979, Aguon 1983). This pattern is expected if the snake was the major cause of the decline. For smaller birds, the eggs, young, and adults are vulnerable to snakes, whereas for large birds only the eggs and young

are vulnerable. Although large snakes can readily take birds the size of a Mariana crow or Mariana fruit-dove, there are few large snakes in the general snake population (Savidge 1986). Cohorts of various-sized snakes on Guam are strongly skewed toward the smaller snakes, those around 1 m or less in length (Savidge 1986). Snakes of this size are able to take adults of the smaller species of birds, but not adults of the larger birds.

Once snakes colonized various regions on Guam, predation pressure on birds became extreme. Predation rates measured by Savidge (1986) using domestic quail held in snake traps scattered in the forest resulted in 75 percent predation in 4-11 nights at sites where snakes were judged to be dense, and 25 percent and 45 percent predation in 14 nights at two sites where densities were lower.

#### EFFECT OF THE SNAKE ON AVIFAUNA Native Forest Birds

The native forest birds of Guam have suffered more than any other group of birds. Of the 11 native forest birds on Guam in 1945, all but one (the nightingale reed-warbler) were widespread and relatively conspicuous throughout the island (Baker 1947). Now, nine are extinct on the island and the other two, the Mariana crow and the Micronesian starling, are much reduced in numbers. The nightingale reed-warbler was only found in low numbers prior to the spread of the snake, and its disappearance could have been due to causes other than predation by the snake. Of the nine extinct birds, two were endemic species and three were endemic subspecies. Two species, the Guam rail and Micronesian kingfisher, have been taken into captivity and now reside in captive flocks in zoos. It is hoped that these birds can eventually be reintroduced to Guam once control methods have been developed for the snake. The Mariana crow has been slowly declining and, barring some form of human intervention, is expected to soon disappear from Guam. Fewer than 50 crows are believed to remain on Guam. The crow is the largest forest bird on Guam and it is possibly this fact that has allowed it to persist longer than the other species. However, even though most adults have been able to avoid predation, the eggs and young are highly vulnerable and there has been no documented recruitment for several years (R. Beck, pers. comm.). The remaining birds compose a dwindling, senescent population. The Micronesian starling is the only native forest bird that may survive into the future on Guam, although at greatly reduced numbers. The starling is a cavity nester and has been able to colonize a few urban areas and thus avoid predation by the snake. A small population of starlings also resides on Cocos Island, an islet 3 km south of Guam.

The island swiftlet is a unique species on Guam,

nesting and roosting in caves, and we have not included it as a forest bird. Populations have nevertheless declined along with other forest birds, and today only a single active colony in south-central Guam is known. At one time there were perhaps a dozen swiftlet caves on Guam harboring thousands of birds. It is not known if the decline of the swiftlet was caused by the snake. Certain colonies appeared to decline prior to the spread of the snake. Also, swiftlets on the nearby island of Rota, where snakes are not found, disappeared over approximately the same period that the swiftlets on Guam disappeared.

### Introduced Species

Most of the eight introduced birds have declined along with the native species, but they have not become extinct. Counts of the Philippine turtle-dove have declined 80-90 percent since the 1960's and 1970's, and this has been attributed primarily to heavy predation on eggs and young by the brown tree snake (Conry 1987). Conry (1987) found nest success to be only 0.3 percent in forest habitat and 2.5 percent in urban habitat. The brown tree snake was the major cause of nest failure and accounted for 93 and 73 percent, respectively, of all mortality in forest and urban habitats. Several other introduced species, including the chestnut mannikin and the black drongo, have exhibited similar declines.

Most introduced birds on Guam have habits that protect them to some degree from the snake. For example, the black francolin is still found throughout much of southern Guam. Because the francolin is large, most snakes are not able to take adults. Also, the francolin is a resident of open fields and savannas, areas that are not favorite habitats of the snake. The Eurasian tree sparrow and rock dove remain mostly around urban centers where snakes are found in low numbers, and thus avoid heavy predation. The black drongo can still be found in low numbers throughout much of the island. Its persistence on Guam is attributed to its habit of nesting on top of power poles and other man-made structures that are difficult for the snake to climb.

### Seabirds

Three species of seabirds were resident on Guam when the snake arrived, the white-tailed tropicbird, brown noddy, and white tern. All three are virtually extinct on the main island, although the noddy and tern can still be found on offshore islets. The disappearance of these birds is most likely due to predation on the eggs and young by the snake.

### Native Species that Remain

Three species of native, resident birds, the yellow bittern, Pacific reef-heron, and common moorhen, appear to have been minimally affected by the snake. Certain

facets of the ecology and biology of these species have probably made them better able to cope with the snake than most of the forest birds of Guam. All are large, aggressive birds which as adults would be difficult prey for most snakes. Losses to snake predation would most likely consist of eggs or young. The yellow bittern and common moorhen typically nest in wetlands, which is not considered typical habitat for the snake. The reef-heron nests on rocky, offshore islets, again habitat that is protected from snakes. Because they are large and aggressive, all three species may be able to defend their nests to some extent against snakes.

## SECONDARY EFFECTS OF THE SNAKE ON GUAM

### Terrestrial Fauna

In addition to causing the disappearance of birds on Guam, the snake has had a dramatic effect upon other fauna. Introduced rats (mostly *Rattus rattus*) and shrews (*Suncus murinus*) were once common in the forests of Guam (Baker 1946, Barbehenn 1974), but today are rarely found. Savidge (1986) found rats and shrews to be more common in savannas and urban areas, both non-preferred habitats of the snake. There is evidence that the native Mariana fruit bat (*Pteropus mariannus*) may also be declining due to predation by the brown tree snake (G. Wiles, pers. comm.). Several species of lizards and geckos were once common on Guam (M. Falanruw, pers. comm.), but are now rare. Our observations suggest that rats, skinks, and geckos are more common on the Mariana Islands north of Guam than on Guam. This difference is probably attributable to predation by the snake on Guam.

### Socioeconomic Problems

The snake has caused a number of socioeconomic problems on Guam. Most notable is the adverse human reaction to a large, mildly venomous snake frequently found in houses and other buildings. Economically, one of the most serious problems is the frequent power outages due to electrical shorts caused by the snake crawling among power lines. Analysis of this problem indicates that power outages due to the snake have cost millions of dollars a year (Fritts 1984, Fritts et al. 1987). The loss of poultry and cage birds to snakes has been another problem with economic implications.

### THREAT OF DISPERSAL

Much of the cargo entering Micronesia, as well as other parts of the Pacific, is transshipped through Guam. Because of the high density of brown tree snakes on Guam, and because of the snake's propensity to seek refuge during the day in dark, secluded crannies, the snake is likely to infest cargo and baggage originating on Guam.

The snake may eventually become established on other islands in the Pacific via such cargo, and ecological disasters similar to that on Guam are likely to occur. The snake has already been discovered in several extralimital localities in addition to Guam, although no reproductive populations are known to have become established. Brown tree snakes have been found in Honolulu, Hawaii, on Wake Island, on Kwajalein Atoll, and on Diego Garcia Atoll (Fritts 1987). Most of these snakes have been in military air and marine ports where the snakes likely arrived in cargo from Guam instead of islands where the brown tree snake occurs naturally (Fritts 1987).

It seems only a matter of time before other extralimital populations become established. The tendency of this snake to be carried to other areas and eventually become established stems from several ecological and biological traits of the snake. It is tolerant of disturbed habitats and can maintain dense populations near shipping ports. It is nocturnal, and readily escapes detection in or around cargo. It is able to live for long periods of time without food, and is thus able to survive for long periods in ships' holds or cargo bays of aircraft. Finally, the broad range of feeding habits ensures that snakes arriving in new environments will adapt to available lizard, bird, and mammal prey species, and will therefore be likely to successfully colonize the island.

#### FUTURE MANAGEMENT ACTIONS

The brown tree snake has seriously affected the ecology, economy, and general quality of life on Guam and is likely to cause similar problems on other islands in the Pacific if it becomes established on them. The primary objective of Territorial and Federal conservation agencies is to control and eradicate the snake on Guam and to prevent its spread to other parts of the Pacific. The ability of Territorial and Federal agencies to respond to the situation on Guam is severely limited by the lack of knowledge about the snake and the control of snake populations in general. Before effective control methods can be implemented, information will be needed about the biology and ecology of the snake on Guam and in its native range, particularly about densities, sources of mortality, habitat use, reproductive habits, feeding behavior, and movements. Once this information is available, control methods for the brown tree snake need to be developed and implemented. This will involve the ability to detect, monitor, capture, and kill or exclude snakes. Particularly important will be the development of appropriate attractants, traps, baits, toxicants, repellents, and methods of biological control. The control technologies developed on Guam will serve in minimizing dispersal from Guam to other islands, and in the eradication of any individuals or populations that may be established on other islands.

Preventing dispersal will involve programs on Guam as well as on potential islands of colonization. Early detection of newly established populations is critical to any attempt to eradicate or control the snake. This will require vigilance to detect, capture, and eradicate snakes that might arrive on an island and therefore reduce the probability of a population becoming established. Informing people on Guam of the potential problem that could develop on other islands will be the first step toward reducing this threat. Training for military and civilian personnel, preparation of technical information, and the establishment of protocols for detecting and reporting potential problems are needed. The degree of threat of invasion to any island will depend upon the type of cargo and traffic from Guam, the frequency of such shipments, and the specific conditions at the point of entry. On high-risk islands, appropriate government agencies should be informed about the problem. All those involved in transportation, inspection, and distribution of cargo should be included. Because most island residents are unfamiliar with snakes, training of personnel in detecting snakes and responding to sightings is needed. Risk posed by military traffic will require close coordination of the diverse military units involved in the transportation of equipment, supplies, and personnel from or through Guam. The development of cooperation and communication among the diverse organizations involved in control of the snake is an important task.

It is now too late to save several endemic species and subspecies that have become extinct on Guam. However, if the snake can be controlled, it may be possible to reintroduce native birds that are held in captive flocks or that are still found on other islands. Controlling the snake will not only benefit the remaining birds of Guam, but will reduce the chance of accidental introductions of the snake to other Pacific islands. At greatest risk are the 80 or so bird species resident in Micronesia, but even avifauna communities much farther from Guam, such as those in Hawaii, are threatened by this efficient predator.

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