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Physiological evidence for reproductive suppression in the introduced population of brown tree snakes (*Boiga irregularis*) on Guam

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Abstract

Introduced species are an increasingly pervasive problem. While studies on the ecology and behavior of these pests are numerous, there is relatively little known of their physiology, specifically their reproductive and stress physiology. One of the best documented introduced pest species is the brown tree snake, *Boiga irregularis*, which was introduced onto the Pacific island of Guam sometime around World War II. The snake is responsible for severely reducing Guam's native vertebrates. We captured free-living individuals throughout the year and measured plasma levels of stress and sex hormones in an effort to determine when they were breeding. These data were compared to reproductive cycles from a captive population originally collected from Guam. Free-living individuals had chronically elevated plasma levels of the stress hormone corticosterone and basal levels of sex steroids and a remarkably low proportion were reproductively active. These data coincide with evidence that the wild population may be in decline. Captive snakes, had low plasma levels of corticosterone with males displaying a peak in plasma testosterone levels during breeding. Furthermore, we compared body condition between the free-living and captive snakes from Guam and free-living individuals captured from their native range in Australia. Male and female free-living snakes from Guam exhibited significantly reduced body condition compared to free-living individuals from Australia. We suggest that during the study period, free-living brown tree snakes on Guam were living under stressful conditions, possibly due to overcrowding and overexploitation of food resources, resulting in decreased body condition and suppressed reproduction.

Keywords: Brown tree snake; *Boiga irregularis*; Introduced pest; Guam; Stress

1. Introduction

Invasive pest species are one of the most pervasive problems being addressed in conservation efforts today (Mack et al., 2000; Vitousek et al., 1996). As such many studies have investigated the impacts that invasive species have had on the ecology, behavior, and physiology of native species (D'Antonio and Dudley, 1995). While there have been a number of studies investigating the

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ecology of the invader, little is known of the physiology of the invader. We are beginning to gain a better understanding of what makes a good invader, but for conservation efforts to be successful we need to know as much as possible about the physiology of the invader. Gaining a general understanding of the breeding biology and the stresses the invader is exposed to could assist focusing management efforts (Wingfield et al., 1997). For example, efforts to interrupt breeding would be most successful during the animal's breeding season.

We know essentially nothing about the stressors faced by invasive species when they invade a new environment. Potential initial stressors could include a lack of shelter, adverse climate, and a lack of food availability. After an invader is established, potential stressors could include overcrowding and the loss of prey as native species are extirpated. When levels of stress are high, the standard vertebrate response is to activate the hypothalamic–pituitary–adrenal axis and release adrenocorticosteroids into the bloodstream (Wingfield and Romero, 2001). As stress and reproduction are generally thought to oppose one another, periods of high stress could disrupt reproduction (Greenberg and Wingfield, 1987; Moore and Jessop, 2003). This may include a decrease in plasma sex steroid levels when stress and plasma andrenocorticosteroid levels increase (Moore and Jessop, 2003; Moore et al., 2000a). The chronic or long-term effects of stress can include complete inhibition of the reproductive system (Wingfield and Ramenofsky, 1999). Plasma levels of corticosterone, the primary adrenocorticosteroid in reptiles, have been shown to be a good estimate of the amount of physiological stress to which the animal is exposed (e.g. Romero and Wikelski, 2001). This study attempts to address if an invader is stressed in a new environment and what effect this is having on reproduction. For this we chose to investigate the brown tree snake, *Boiga irregularis*, on Guam.

The brown tree snake is a pest species on the Pacific Island of Guam where it was introduced sometime during or immediately after World War II. After its introduction to Guam, the population erupted, expanding its range across the entire island (Rodda et al., 1992). High densities of this generalist predator have led to the depletion of most of Guam's native vertebrate fauna (Wiles et al., 2003). Fritts and Rodda (1995) reported that all of Guam's surviving endotherm populations consist of less than 1000 individuals and the viability of these populations is questionable. Brown tree snake predation has had an adverse effect on 17 of 18 native species on Guam including various small mammals, lizards, and the extinction or extirpation of 12 bird species (Savidge, 1987; Rodda et al., 1997; Wiles et al., 2003). These negative effects of the brown tree snake could be repeated if the snake gets established on other islands (it has been already seen on Hawaii).

Peak densities of over 100 brown tree snakes per hectare on Guam were measured in the mid-1980s, preceded by apparently continuous population growth from the time of introduction (Rodda et al., 1992, 1999b). Subsequent surveys in the early 1990s found lower peak snake densities (20–50 snakes per hectare) along with more variable levels depending on location on the island (Rodda et al., 1992). It is thought that depleted food resources have led directly to declines in brown tree snake densities on Guam (Fritts and Rodda, 1995). Such declines may be due to adult mortality and/or suppressed reproduction in the population. Wiles et al. (2003) suggest, without presenting data, that a dramatic decline in body condition since 1985 supports the premise that the population is in decline.

In its native habitat of Australia, the brown tree snake displays a cyclic reproductive cycle in both female gamete production and male testicular activity (Bull and Whittier, 1996, 1997; Shine, 1991; Whittier and Limpus, 1996). On Guam, we know little about the seasonal reproductive cycle of the snakes as few mature, reproductively active snakes have been found during sampling (Mathies et al., 2001; Rodda et al., 1999a). Rodda et al. (1999a) estimated that only 0.5% of total captures on Guam were reproductively active females. In histological and morphological samples collected on Guam over a two-year period as part of this study, Mason et al. (unpublished) found that only six of 128 females had vitellogenic follicles. Population data indicate that there is a smaller fraction of mature adults in the Guam population compared to either the native, Australian population or to data for other snake species (Rodda et al., 1999b).

The aim of this study was to examine physiological mechanisms that may explain the low proportion of reproductively active adults on Guam by examining seasonal cycles of reproduction, stress, and body condition of the brown tree snake. We predicted that in the Guam brown tree snakes, low body condition would be accompanied by high levels of stress hormones and low levels of sex steroids in comparison with the native populations from Australia and captive populations. More specifically, we compared plasma levels of sex (testosterone in males, 17β-estradiol and progesterone in females) and stress (corticosterone) steroid hormones between free-living snakes on Guam and breeding captive snakes originally collected on Guam. We also compared body condition between these two groups and free-living individuals from a native population from Australia. The data from this study will complement current management efforts designed to control introduced brown tree snake populations; for example, applied research methods to manage brown tree snake populations include inhibiting reproduction using chemical and immunological fertility control (Brown Tree Snake Control Committee, 1996).