Herpetological Conservation and Biology 7(2): 219–226.
Submitted: 20 November 2011; Accepted: 2 July 2012; Published: 10 September 2012.

DOES THE INVASIVE SHRUB *ULEX EUROPAEUS* BENEFIT AN ENDEMIC SRI LANKAN LIZARD?

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***Abstract.*—The spread of invasive plants poses a serious threat to the composition, structure, and function of biotic communities world-wide. Some native animals, however, adapt to use invasive plants as living spaces. We studied such a relationship between the invasive bush European Gorse (*Ulex europaeus*) and the endemic Black-cheeked Lizard (*Calotes nigrilabris*) in the highlands of Sri Lanka. We found that *C. nigrilabris* use habitats non-randomly and prefer *Ulex* bushes over native and other introduced vegetation in disturbed habitats. The selection of these bushes as living spaces by lizards may be driven by both reduced predator risk and increased foraging benefits. Thus, restoring the ecological functions of *Ulex* should be considered in planning future eradication programs.**

Key Words.—Agamidae; *Calotes nigrilabris*; foraging benefits; habitat restoration; Horton Plains; predator avoidance

INTRODUCTION

Many species introductions into new geographic areas are well known for their negative effect on native species (Usher 1986; Shine 2010). Plant invasions in particular have been shown to have negative effects on native plant and animal community structure, species diversity and abundance, and also on higher trophic levels (Levine et al. 2003). Invasive plants can threaten biological communities (Alpert et al. 2000; Simberloff 2005) and can affect native ecosystem functions via many pathways including competition (e.g. Galbraith-Kent and Handel 2008), toxication (e.g., Maerz et al. 2005), and disease transfer (Crowl et al. 2008).

In many cases, however, while some native species will experience negative effects in the presence of an invasive species, others may benefit from the invader's dispersion (Simberloff 2006; Llewelyn et al. 2009). A large body of literature is rapidly accumulating on the positive impacts of invasive plant species, for example, invasive plants may provide food and shelter-sites for native and domesticated taxa (Barrau and Devambez 1957; Schiffman 1994; Shine and Fitzgerald 1996; Low 1999). Many native animals use invasive plant species as habitat (Wright and Gribben 2008; Thomsen 2010), and native fauna can sometimes reach higher diversity and abundance in habitats associated with invasive plants compared with uninvaded habitats (Sax et al. 2005; Rodriguez 2006). It is, however, often largely unknown how life-history traits and fitness of native fauna respond to habitat-forming invasive species, and thus whether fauna gain a net benefit from that association (Wright and Gribben 2008).

European Gorse (*Ulex europaeus*; Fig. 1a), native to the Atlantic coast of Europe and the British Isles including Ireland (Hill et al. 2008), was introduced to the central highlands of Sri Lanka in 1888 (Wijesundara 1999). Gorse has proven to be an aggressive invader forming impenetrable, largely monotypic stands that reduce access by grazing animals, modify native ecosystems and ecosystem processes, and out-compete trees in regenerating forests (Hill et al. 2008). The plant may live about 30 y (Lee et al. 1986) and seeds could survive in the soil for a similar period (Moss 1959). It is currently naturalized in the montane region of Sri Lanka, especially at Horton Plains National Park (HPNP) and its environs (Fig. 1a), and is considered an 'Invasive Alien Species,' threatening native ecosystems and biodiversity (Marambe 2001). Therefore, considerable effort is continuously invested by governmental departments and community groups in the removal of this plant from HPNP (Department of Wildlife Conservation 2008).

The endemic Black-cheeked Lizard (*Calotes nigrilabris*; Fig. 1b) inhabits the submontane and montane regions of Sri Lanka (Somaweera and Somaweera 2009). It is a diurnal and arboreal agamid using low shrubs and ferns near the ground but sometimes climbing trees up to several meters. It is locally common at HPNP and nearby areas, including Nuwara Eliya, but due to its limited distribution (approximate area of occurrence is 300 km^2: Bahir and Surasinghe 2005), *C. nigrilabris* is considered 'Nationally Threatened' and 'Vulnerable' (IUCN Sri Lanka and the Ministry of Environment and Natural Resources 2007). In this study, we investigated whether *Calotes nigrilabris* actively select *Ulex europaeus* over other vegetation, and if so, the reasons for such selection. We also investigated whether the individual

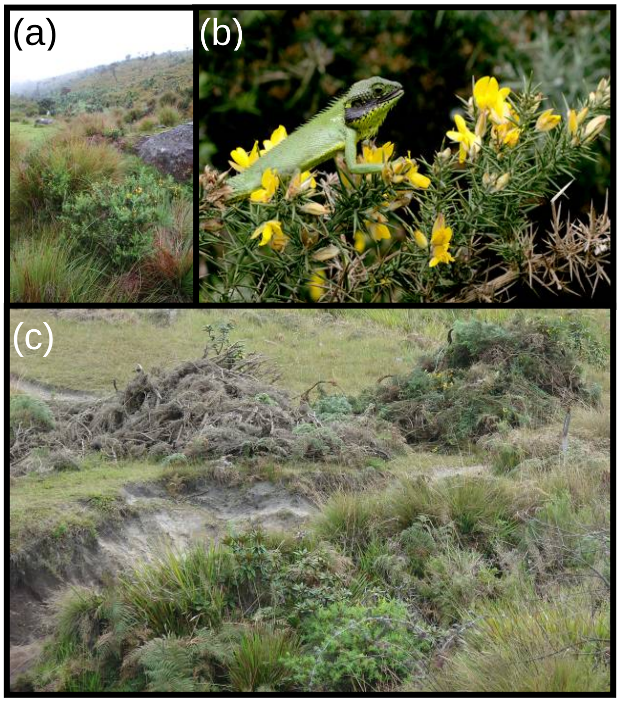

FIGURE 1. European Gorse (*Ulex europaeus*) among native grasses and other bushes at Horton Plains National Park, Sri Lanka (a) are commonly inhabited by Black-cheeked Lizards (*Calotes nigrilabris*), especially when the plants are in flower (b). Mechanical removal of Gorse was widely conducted as a step towards controlling this invasive plant (c). (Photographed [a and b] by Ruchira Somaweera, and [c] by Sameera Karunarathna).

fitness of lizards is higher in the invaded habitat compared with the native habitats.

MATERIALS AND METHODS

Study location.—We conducted the experiments at HPNP and the area surrounding the town of Nuwara Eliya in Sri Lanka. This area experiences a subtropical monsoon climate, with a mean annual temperature of 15 °C and mean annual rainfall of 2150 mm (Department of Wildlife Conservation 2008). The vegetation in natural habitats comprises upper montane rain forests (sometimes comprising 'cloud forests') and wet 'patana' grasslands, with a narrow ecotone of shrubs and herbs between them (Gunatilleke and Gunatilleke 1986). In habitats close to human habitations there was a mosaic of crops, naturalised exotic horticultural plants, and native shrubs. Extensive areas in the region have been cleared in the recent past for human settlements, tea plantations, and vegetable farming (Department of Wildlife Conservation 2008), and the remaining cloud forests suffer from canopy die-back, possibly due to imbalance of macro- and micronutrients in the soil (Chandrajith et al. 2009). More than 50 species of invasive plants have become established through cultivation in gardens and as a result of vegetable cultivation farming in the region (Pethiyagoda and Gunatilleke 2006).

In June-July 2011, we surveyed selected sites as a part of a larger study on the ecology of montane lizards. *Ulex* bushes were always found as small, distinct patches or lines, most often close to native or introduced vegetation (commonly called 'other shrubs' hereafter). We selected five 50 × 50 m sites containing both vegetation types: *Ulex* bushes and other shrubs, close to human habituated areas (< 1 km from garbage dumps and buildings) and five sites (containing both vegetation types) from undisturbed areas (> 2 km from human habitations). We presumed it possible that different predation pressures from native opportunistic fauna exist close to and far from human-impacted areas (see below).

Preference of bushes.—To measure the availability of vegetation types, we delineated each vegetation type (*Ulex* bushes and other shrubs) on a 1:20,000 topographical map during ground surveys and we measured the amount of vegetation type (*Ulex* bushes vs other shrubs) available at each of the 10 study sites. At each site, we laid two 20 m line transects and counted the number of lizards (adult male [M], adult female [F], and juvenile [J] categories) within 2 m of transects. We randomly selected transects (but avoided them overlapping or crossing over each other within a given study site); commenced surveys at 1000 when lizards were frequently seen to be active, and continued surveying until ~1400 with two observers spending 12–15 min searching for lizards at each transect. For each lizard observed, we recorded the type of vegetation it was in (either *Ulex* bushes or other shrub) and the category (M/F/J) of the lizard. We measured the air temperature at the start and end of surveys and averaged values for each survey.

Predator pressure.—Because predatory birds are highly mobile, we assumed that the birds observed had a similar predation pressure on animals inhabiting *Ulex* bushes and other shrub within a site. Hence, we increased the plot area in which we took spot counts up to ~200 × 200 m (while our study units were only 50 × 50 m). We surveyed five sites in disturbed habitats and five in undisturbed habitats. Observations of birds were made from a blind (from within a bush at a corner of the site) on two days by two observers. A given observer conducted the surveys at a given site on both days. We counted the numbers of feeding and roosting birds at each site (40,000 m^2 area) between 0900–1100 and then at 1500–1700 on two consecutive days. During the surveys, we categorized birds as crows or raptors and recorded all predation attempts. Our intention was to estimate the activity of the two bird groups within the plot; thus some individuals might have been counted more than once. We did not conduct surveys when heavy rain or high winds were occurring; by controlling for these conditions we did not need to account for their effects on detection probability.

Effects of flowers.**—**To test whether the presence of flowers had any effect on lizards selecting *Ulex* bushes in undisturbed habitats (> 2 km from human habitations), we removed all flowers from *Ulex* bushes in five sites (20 m long transects) after an initial survey and enumeration of lizards. We cut the flowers from the pedicel using sharp scissors at 0630–0730 when lizards were not observed on the bushes (possibly lying close to the roots). Subsequently, we surveyed these five transects and five other 20 m transects with flowers on alternate days (commencing at 1000 and surveying each transect for 10–15 min by two observers) for four times to investigate the effect of flowers on the habitat selection of lizards. We measured air temperature at the beginning of each survey.

Statistical analysis.**—**We analysed the data using the statistical software JMP 5.01 (SAS Institute, Cary, North Carolina, USA). We compared densities of lizards by sex and predators between different habitat types, vegetation types, and the interaction of each main effect using a two-way ANOVA ($\alpha = 0.05$). We analyzed the effect of flower removal on lizard densities using both a repeated measures ANOVA and a paired t-test ($\alpha = 0.05$). Multivariate repeated measures ANOVA (MANOVA) was used to analyse the interaction between flower removal and time on lizards occupying *Ulex* bushes. When appropriate, we log (x + 1) transformed data with non-normal distributions to achieve variance homogeneity before statistical analysis.

RESULTS

Preference for bushes.**—***Ulex* bushes and other shrub comprised 12.3% and 26.5% of the total area of the 10 study sites, respectively. The rest comprised grasses (*Chrysopogon nodulibarbis*, *Andropogon polyptychos*, and *Axonopus fissifolius*), Dwarf Bamboo (*Arundinaria densifolia*), and larger trees and bare ground. We observed 114 lizards (47 M, 46 F, 21 J) within the 20 transects (a total area of 1600 m^2) during approximately 16 person-hours of survey. The densities of lizards differed by sex ($F = 3.53$, df = 2,54, $P = 0.04$; posthoc Fisher's PLSD test, $P < 0.05$ for juveniles compared to males and females) but not between disturbed (0.033 lizards per m^2) and undisturbed (0.038) habitats ($F = 0.28$, df = 1,54, $P = 0.60$), or between *Ulex* bushes (0.041) and other shrub (0.031; $F = 1.70$, df = 1,54, $P = 0.20$). The densities of each sex were neither significantly different between habitat types (habitat type x sex: $F = 0.09$, df = 2,54, $P = 0.91$) nor between vegetation types (vegetation type x sex: $F = 0.66$, df = 2,54, $P = 0.52$). However, when the effect of the interaction between vegetation type and habitat type is considered, densities of lizards differed significantly between *Ulex* bushes/other shrub in disturbed/undisturbed habitats (habitat type x vegetation type: $F = 4.22$, df = 1,16, $P = 0.05$) with other shrubs in disturbed habitats having the least density of lizards (posthoc Fisher's PLSD test, $P < 0.05$ for comparison; Fig. 2). Air temperature did not influence counts among sites ($R^2 = 0.008$, $F = 0.49$, df = 1,58, $P = 0.48$).

Predator pressure.**—**We found crows in both disturbed and undisturbed habitats but their numbers were significantly higher in the disturbed habitats: 85 vs 16 during 40 hr of survey in each habitat type ($F = 21.64$, df = 1,38, $P < 0.001$; Fig. 3). At a given site, the level of crow activity was similar between the two days of survey (habitat type x survey #: $F = 0.22$, df = 1,36, $P = 0.64$) and between the two survey times on a given date (survey # x time: $F = 3.84$, df = 1,36, $P = 0.06$). In contrast, the number of raptors recorded in the two habitat types did not differ significantly ($F = 1.88$, df = 1,38, $P = 0.18$). We did not observe any crows or raptors preying on lizards during the study.

Effects of flowers.**—**There was no significant difference in mean lizard numbers in bushes with (0.26 individuals) and without (0.21) flowers ($t = 1.09$, df = 1,19, $P = 0.28$). There was no effect of the presence of flowers ($F = 0.08$, df = 1,8, $P = 0.47$) but there was a significant interaction between flowers and time (MANOVA days x flowers: $F = 2.99$, df = 3,6, $P = 0.03$). The number of lizards in the plots where flowers were removed decreased significantly with time (Fig. 4.).

DISCUSSION

The habitats that animals select can profoundly affect their access to food, their growth rates, their risk of predation, and their future survival. Our brief study shows that *Calotes nigrilabris* would commonly use *Ulex* bushes as living space, about equally in both disturbed and undisturbed habitats. However, our comparisons show that the lizards used habitats non-randomly: the lizard densities were significantly lower within other shrub in disturbed habitats, despite this vegetation type being more abundant than *Ulex* bushes. Because our estimates of potential predator activity in disturbed habitats are high, these results may reflect these lizards experiencing greater protection within *Ulex* bushes in disturbed habitats. Our studies on flower removal suggest that lizards may also have foraging benefits from these plants.

Black-cheeked Lizards prefer open habitats (Erdelen 1988; Somaweera and Somaweera 2009; Karunarathna

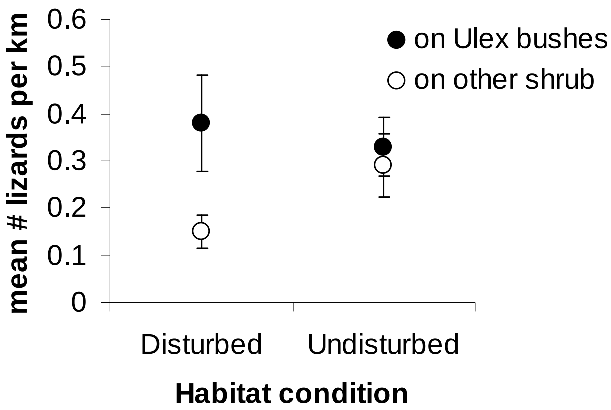

FIGURE 2. The density of *Calotes nigrilabris* on *Ulex europaeus* bushes and other shrub in disturbed and undisturbed habitats in Horton Plains National Park and Nuwara Eliya. Despite *Ulex* being less abundant than the other shrubs, significantly more lizards were seen on *Ulex* bushes in disturbed sites. Error bars indicate standard errors.

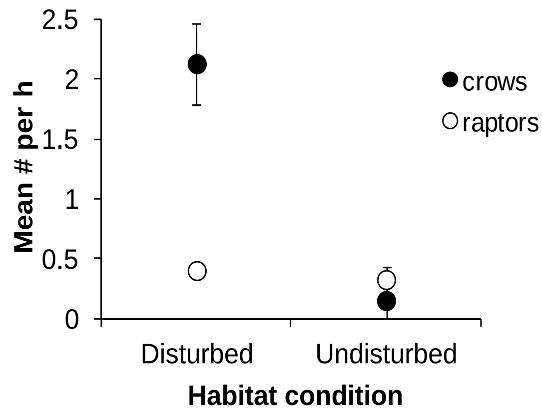

FIGURE 3. Activity of crows and raptors in disturbed and undisturbed habitats at Horton Plains National Park and Nuwara Eliya. The number of crows active within the five sites in disturbed habitats was significantly higher than those in undisturbed habitats. Raptors had similar activity patterns under both habitat conditions. Error bars indicate standard errors.

et al. 2011) and could reach very high densities of up to 220 individuals per hectare in these habitats (Erdelen 1988). The very high estimates during this study (114 in 0.16 ha) could be a result of actively selecting shorter transects within the most likely places the lizards could be rather than randomly in the grasslands. Thus, these lizards would offer a common source of food for raptors as well as other native opportunistic predators such as Greater Coucals (*Centropus sinensis*), Sri Lanka Whistling Thrush (*Myophonus blighi*), and Feral Cats (*Felis catus*; Warakagoda 1997; de Silva 2007; Somaweera, pers. obs.). However, currently one of the major predators of lizards at HPNP and nearby areas is the Jungle Crow, *Corvus macrorhynchos* (de Silva 2007; Karunarathna and Amarasinghe 2008; Somaweera and Somaweera 2009). This species was not reported from the highlands of Sri Lanka until recently (Kotagama and Fernando 1994; Henry 1998). Although there are no quantified estimates, the Jungle Crow has now established large populations in human dominated areas in the highest tablelands (pers. obs.), a trend commonly attributed to the availability of food as in garbage dumps. Corvids are often considered responsible for preying on small animals and are, therefore, of conservation concern (Cox et al. 2004). This opportunistic feeder also consumes small reptiles, mammals, and amphibians (Henry 1998). How *Ulex* provides protection to lizards from crows warrants attention. Unlike raptors that catch prey with talons, crows catch prey with their beaks (e.g. Phillips 1978; Rassati 2010). Attempts to catch prey with the foot have been reported to be unsuccessful (Heathcote 1978). Thus, unless the prey is taken in flight (e.g. Edholm 1979; Trolliet and Marguerat 2009), corvids may have to either ground the prey (e.g. Lefevre 2005) or perch on the substrate to catch it (Adams 1973; Karunarathna and Amarasinghe 2008). However, the structure of the *Ulex* plant (vertical thorny stems) would not permit larger birds to perch and take prey. Also due to the often dense base of *Ulex* bushes (the compactly positioned *Ulex* stems are frequently surrounded by grass), it may be difficult for a predator to walk into the bush following an escaping lizard.

Our results also show that lizards may prefer *Ulex* bushes in flower over those without flowers. The yellow flowers of *Ulex* are pollinated by honey bees (Gunatilleke 2007) and a number of other insects including butterflies visit these flowers (Wijayathilaka, pers. obs.). Thus it appears that the lizards would have higher foraging benefits by inhabiting bushes continuously in flower (Gunatilleke 2007; current study) over those that are not. Flowering onset and duration of *Ulex* varies greatly, both within and among populations (Tarayre et al. 2007), and flowering at the population level could last up to nine months of the year (Markin and Yoshioka 1996). Though a comparison of food availability in *Ulex* bushes and other shrub would give valuable information with regard to the importance of *Ulex* as a foraging habitat, this is logistically difficult to achieve. *Calotes nigrilabris* has been observed foraging also close to flowers of the native tree *Rhododendron arboreum* and the shrub *Hypericum mysurense* (Somaweera pers. obs). Future work should look into the prey choice and foraging behaviour of these lizards to make more robust conclusions on the importance of different vegetation types as foraging grounds.

Ulex has being long considered a major threat to the biodiversity in the montane zone of Sri Lanka (e.g. Wattavidanage 2006; Department of Wildlife Conservation 2008) and elsewhere (see review by Hill et al. 2008). Our

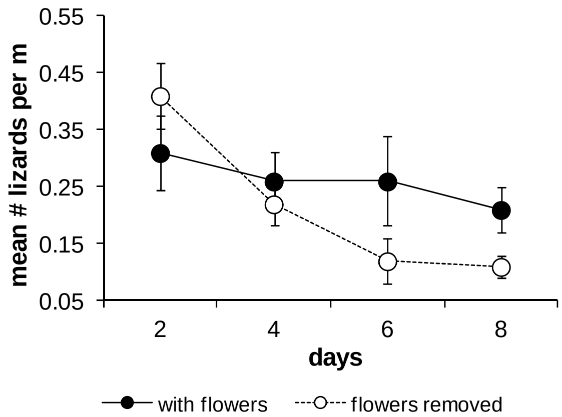

FIGURE 4. The effect of removing flowers in *Ulex europaeus* shrubs on the number of *Calotes nigrilabris* inhabiting the plants. Flower removal reduced the number of lizards inhabiting the bushes over time. Error bars indicate standard errors.

study is not the first to identify the importance of *Ulex* to the herpetofauna of Sri Lanka, however. Marambe et al. (2001) noted that removal of *Ulex* in montane grasslands could expose endemic herpetofauna that use these bushes to predators. Work elsewhere shows that there could be benefits to native fauna: in the high Andean, the native birds *Diglossa humeralis* and *Basileuterus nigrocristatus* were more abundant in forest edges invaded by *Ulex* (Amaya-Villarreal and Renjifo 2010), and in New Zealand, *Ulex* habitat was more species rich compared to native habitats for several native invertebrate groups (Harris et al. 2004). At HPNP *Ulex* is a key feeding plant for Honey Bees (*Apis mellifera*; Gunatilleke 2007), and for the larvae of the Pea Blue (*Lampides boeticus*) butterfly (Wijayathilaka, pers. obs). The young shoots of *Ulex* have been consumed by the principal ungulate at HPNP, the Sambar, *Cervus unicolour* (rangers at HPNP, pers. comm.), although Padmalal et al. (2003) did not find *Ulex* in the scat of Sambar at HPNP.

Management of *Ulex* has being conducted through biological control elsewhere (e.g. Hill et al. 2008; Ireson et al. 2008), but mainly through mechanical removal in Sri Lanka (Department of Wildlife Conservation 2008). An area of ~5 km^2 is cleared yearly at HPNP by community groups as a step towards restoring the natural grassland habitat. Most such removals in the past were haphazardly done (Marambe et al. 2001) and may have had negative impacts on the ecosystems as well as native wildlife. Areas from which *Ulex* is cleared could be prone to further invasion by yet more aggressive alien species such as Austroeupatorium (*Austroeupatorium inulifolium*), as the restoration process results in disturbance and increased resource availability (D'Antonio and Meyerson 2002; DeMeester and Richter 2009), but could also expose their inhabitants to predation. Shine and Fitzgerald (1996) found that patches of introduced plants were vital for the continued presence of large Carpet Pythons (*Morelia spilota*) in an agricultural landscape in Australia. Thus, under certain circumstances, retaining exotics under controlled conditions may benefit natives in degraded natural habitats (such as our sites around Nuwara Eliya).

The problem of optimal management of invasive species is a difficult one in part because managers must operate with limited information. Given the high invasiveness of *Ulex*, it needs to be removed from the environment in Sri Lanka, arguably in a phased manner. Nevertheless, our brief study demonstrates that *Ulex* plays a potentially significant ecological role, providing refuges and foraging benefits for the endemic Black-cheeked Lizards. Future plans to eradicate *Ulex*, therefore, need to consider retaining the ecological functions of the species while eradicating the plant.

Acknowledgments.—We thank Samantha Bombuwalage and Harindu Jayakody for their help with field work and the warden and staff at Horton Plains National Park for logistical support. Rohan Pethiyagoda made useful - comments on the manuscript and Sameera Karunarathna provided a photograph. This work was conducted as a component of a larger project under research permits from Department of Wildlife Conservation of Sri Lanka (Permit No. WL/3/2/1/7) and funding from the National Geographic Society.

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